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NEW SPECIES AND A CATALOGUE OF STIGMODERA (CASTIARINA) (COLEOPTERA: BUPRESTIDAE)

BY S. BARKER

Summary

Stigmodera rudis Carter is reinstated in the sub-genus Castiarina. Thirteen new synonyms are given and two species are resurrected from the synonymy. One name has been wrongly synonymised. A lectotype of S. rubriventris Blackburn is selected. Seven new species of Stigmodera (aliceae, aquila, aurea, hateleyi, inflata, kiatae, mimica) are described and illustrated.

NEW SPECIES AND NEW SYNONYMS OF *STIGMODERA (CASTIARINA)* (COLEOPTERA: BUPRESTIDAE)

by S. BARKER*

Summary

BARKER, S. (1980) New species and new synonyms of *Stigmodera* (*Castiarina*) (Coleoptera: Buprestidae). *Trans. R. Soc. S. Aust.* 104(1), 1-7, 29 February, 1980.

Stigmodera rudis Carter is reinstated in the sub-genus *Castiarina*. Thirteen new synonyms are given and two species are resurrected from synonymy. One name has been wrongly synonymised. A lectotype of *S. rubriventris* Blackburn is selected. Seven new species of *Stigmodera* (*alleeae, aquila, aurea, hateleyi, inflata, kiatae, mimica*) are described and illustrated.

Introduction

Despite the wide occurrence of *Stigmodera* (*Castiarina*) species in Australia, some have a restricted distribution, are not represented in Museums and are difficult to obtain. Since my catalogue of *Stigmodera* (*Castiarina*) (Barker 1979) I have borrowed or collected specimens of a number of species previously unavailable. From a comparison with types, photographs of types and examination of male genitalia, I now recognise seven new species and synonyms that I had missed previously.

Stigmodera (Castiarina) rudis Carter 1934

FIG. 1

I have examined a complete male specimen. It is a lycid mimic and, except that it has a hairy head, antennae and pronotum, resembles all other *Stigmodera* (*Castiarina*) and should be included in the sub-genus. It was collected on flowers of *Leptospermum* sp. at Lake Dobson National Park, Tasmania, at an elevation of 914 m on 19.i.1951 by J. R. Cunningham. Barker's (1979) key to *Stigmodera* should be modified so that the second phrase of the 2nd couplet appertaining to *Castiarina* reads, "seldom with hair on dorsal surfaces of head and pronotum".

Additions to synonymy of *Stigmodera (Castiarina)*

australasiae L. & G. 1837, Mon. Bupr. 2, 32
- *assimilis* Hope 1846, *Trans. ent. Soc. Lond.* 4, 212 (new synonym)
- *melbournensis* Thomson 1879, *Typ. Bupr. App.* 1a, 34
- *timida* Kerremans 1898, *Annls Soc. ent. Belg.* 42, 147
- *puerilis* Kerremans 1898, Annls Soc. ent. Belg. 42, 147

carminea Saunders 1868, *J. Linn. Soc.* 9, 474
- *colligens* Kerremans 1890, *Bull. Soc. ent. Belg.* 1890, 44 (new synonym)
- *felix* Kerremans 1898, Annls Soc. ent. Belg. 42, 142

dawsonensis Blackburn 1890, *Trans. R. Soc. S. Aust.* 13, 155
- *pulchella* Carter 1916, *Trans. R. Soc. S. Aust.* 40, 135 (new synonym)

deuqueti Carter 1927, *Proc. Linn. Soc. N.S.W.* 52, 225
- *suttoni* Carter 1932, Proc. Linn. Soc. N.S.W. 57, 104 (new synonym)
- *palagera* Carter 1937, *Trans. R. Soc. S. Aust.* 61, 125 (new synonym)

duaringae Carter 1929, *Proc. Linn. Soc. N.S.W.* 54, 68
- *bogania* Carter 1930, *Proc. Linn. Soc. N.S.W.* 55, 534 (new synonym)

inermis Kerremans 1890, *Bull. Soc. ent. Belg.* 1890, 45
- *nova* Kerremans 1902, *Genera Insect.* 12, 208
- *rubella* Carter 1931, *Aust. Zool.* 6, 345 (new synonym)

media Hope 1847, *Trans. ent. Soc. Lond.* 4, 284
- *septemnotata* Carter 1916, *Trans. R. Soc. S. Aust.* 40, 86 (new synonym)
- *septemmaculata* Blackburn 1892, *Trans. R. Soc. S. Aust.* 15, 45

piliventris Saunders 1868, *J. Linn. Soc.* 9, 474
- *generosa* Kerremans 1898, *Annls Soc. ent. Belg.* 42, 150 (new synonym)

rectifasciata Saunders 1868, *J. Linn. Soc.* 9, 472
- *vigilans* Kerremans 1898, *Annls Soc. ent. Belg.* 42, 143 (recognised by Blackburn 1900 p. 42)

rubicunda Carter 1931, *Aust. Zool.* 6, 346
- *violatra* Deuquet 1956, *Proc. Linn. Soc. N.S.W.* 81, 156 (new synonym)

rufipennis (Kirby) 1818, *Trans. Linn. Soc.* 12, 456
- *crocipennis* L. & G. 1837, *Mon. Bupr.* 2, 21
- *crocipennis* Hope 1846, *Trans. ent. Soc. Lond.* 1846, 292
- *quadrifoveolata* Obenberger 1933, *Čas čsl. Spol. ent.* 30, 69 (new synonym)

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scalaris (Boisduval) 1835, Voyage de l'Astrolobe, 89
cyanicollis (Boisduval) 1835, Voyage de l'Astrolobe, 91
crucigera L & G 1837, *Mon. Bupr.* 2, 40
viridis L & G 1837, *Mon. Bupr.* 2, 46
crucigera Hope 1838, *Col. Man.* 2, 162
macleayi Blackburn 1892, *Trans. R. Soc. S. Aust.* 15, 48 (new synonym)
prudens Kerremans 1898, *Annls Soc. ent. Belg.* 42, 152
suavis Kerremans 1902, *Genera Insect.* 12, 210
crucioides Obenberger 1922, *Arch. Naturgesch.* 88, 118

Species resurrected from synonymy

I listed *S. gravis* Harold, 1869 as a synonym of *S. trifasciata* L & G, 1837 (Barker 1979, p. 22). *S. gravis* was a replacement name for *S. obscuripennis* Saunders, 1868 which is a homonym of *S.* (*Themognatha*) *obscuripennis* Mannerheim, 1837. I have re-examined 10 Western Australian specimens in the South Australian Museum collection. I find that they are identical to a coloured photograph of the type of *S. gravis* and I consider *gravis* a valid species.

I also listed *S. bucolica* Kerremans, 1898 as a synonym of *S. trifasciata* L & G, 1837. I have re-examined 16 unidentified specimens in the South Australian Museum collection, captured near Port Lincoln on the Eyre Peninsula, S.A., and, on the basis of comparison with a coloured photograph of the type, I consider that they represent *S. bucolica* which I now consider a valid species.

In the catalogue of *Stigmodera* (*Castiarina*) I listed *S. subnotata* Carter, 1933 as a synonym of *S. subtincta* Carter, 1933. It has been pointed out to me that these are distinct. I have examined material in the South Australian Museum and in the Western Australian Museum and find that the male genitalia are different; I consider both to be valid species. In *S. subtincta* the last four visible abdominal segments of males are testaceous and of females metallic green. In *S. subnotata* all visible abdominal segments are testaceous in both sexes.

Selection of lectotype of S. rubriventris Blackburn

Describing *S. rubriventris* Blackburn (1900) p. 47 stated, "In one of the two specimens before me." The syntypes are males, one is in the British Museum, the other in the South Australian Museum. Most of Blackburn's types are lodged in the British Museum collection and, all other things being equal, I consider that the type should remain with the majority of specimens. I hereby select the male specimen in the British Museum labelled "W.A. 7556, *S. rubriventris* Blackburn" as the lectotype of the species.

Fig. 1. Male *Stigmodera* (*Castiarina*) *rudis* Carter.

The abbreviations used in the text for museum and private collections are as follows: WADA, Western Australian Department of Agriculture, South Perth; GB, Mr G. Burns, Mornington, Vic.; ANIC, Australian National Insect Collection, C.S.I.R.O., Canberra; JH, Mrs J. I. Harslett, Amiens, Qld; AM, Australian Museum, Sydney; SAM, South Australian Museum, Adelaide; WAM, Western Australian Museum, Perth; MP, Mr M. Powell, Mr. M. Golding & Mr T. M. S. Hanlon, Perth; NMV, National Museum of Victoria, Melbourne.

Stigmodera (Castiarina) mimica sp. nov.
FIGS 2A, 3A

Types: Holotype: ♂, Goldsborough near Gordonvale, Qld, 5.i.1962, *J. G. Brooks,* SAM I21, 106. Allotype: ♀, same data as holotype, SAM I21, 107. Paratype: 1 ♂, Marmor, Qld, xi.1946, *W. du Boulay,* WAM.

Colour: Head, antennae black with blue reflections. Pronotum, scutellum black. Elytra red-brown with black anterior margin, entire apex black, curving upwards from margin 2/3 along its length. Undersurface and legs black with blue reflections. Hairs silver.

Shape and sculpture: Head with small close punctures, median groove between eyes, muzzle short. Antennae: segments 1–4 obconic, 5–11 toothed. Pronotum with small close punctures; median basal fovea projecting forwards as median impressed line to anterior margin; glabrous basal notch on each side 1/3 from margin to centre; anterior to basal notches a large irregular depression on each side; anterior margin projecting forwards in middle; basal margin bisinuate; laterally rounded out from base, widest 1/3 from base, rounded to apical margin. Scutellum: heart-shaped; without punctures; convex in middle; both lobes elongate. Elytra: three broad costae on each side, scutellary, 3rd and 5th intervals; other intervals punctate-striate and flat at basal end, convex at apical end, punctured and rough; laterally angled out from base, rounded at shoulder, concave until after middle, rounded to apex which is bispinose; spines very small, rounded between; apices slightly diverging. Undersurface with small close punctures and short close hairs. Last visible abdominal segment truncate in both sexes. Male with

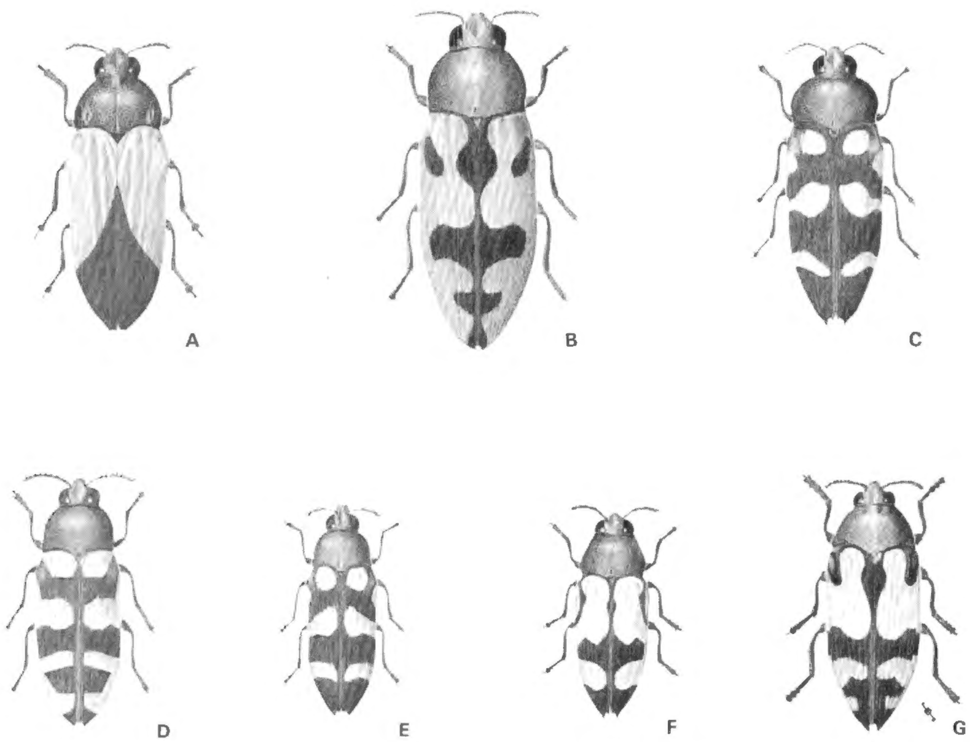

Fig. 2. (x 3) natural size. A. *Stigmodera mimica* sp. nov. B. *S. hateleyi* sp. nov. C. *S. inflata* sp. nov. D. *S. aquila* sp. nov. E. *S. aliceae* sp. nov. F. *S. kiatae* sp. nov. G. *S. aurea* sp. nov.

reduced tarsal pads on 2nd and 3rd legs, pads absent on segments 1–3 replaced with single median spine, pad present on segment 4 only.
Size: Males 11.7 x 4.2 mm (2). Females 12.3 x 4.6 mm (1).
Distribution: North coastal Queensland.
General remarks: A lycid mimic belonging in the *S. sexplagiata* group on the basis of male genitalia and modified tarsal pads in male. Another member of the group *S. erythroptera* is also a lycid mimic and has the same elytral colour. *S. mimica* differs from that species in that it has fovea on the margins of the pronotum: *S. erythroptera* does not. *S. mimica* has a different elytral pattern with more black than in *S. erythroptera*. Elytral marking on *S. mimica* is like that of *S. nigriventris*, also a lycid mimic without costae on the elytra and not a member of the *S. sexplagiata* group.

Stigmodera (Castiarina) hateleyi sp. nov.
FIGS 2B, 3B

Types: Holotype: ♂, Kiata, Vic., *K. Hateley*, SAM I21, 108. Allotype: ♀, Kiata, Vic., *K. Hateley*, SAM I21, 109. Paratypes: 5 ♂ & 2 ♀, same data as holotype, SAM; 2♂ & 2 ♀, Wurarga, W. Aust., 28.x.1978, *M. Powell & M. Golding*, MP, SAM; 1 ♀, Maranalgo Stn, W. Aust., 10.ix.1978, *G. Barron*, MP; 1 ♀, Lake Grace, W. Aust., 16.x.1970, *K. & E. Carnaby*, SAM; 2 ♂ & 1 ♀, Australia, *Blackburn & White*, SAM.
Colour: Head, antennae, pronotum, most of undersurface and legs dark blue with yellow and green reflections, last visible abdominal segment mainly brown in male. Scutellum black. Elytra red-brown with following black markings: narrow anterior margin; elongate angled mark on each shoulder, rounded spot between on suture all remnant of a pre-medial fascia; post-medial fascia projecting forwards in middle of each side and concave backwards, not reaching margin; pre-apical mark extending over three intervals, concave forwards; marks all connected down suture and covering apex. Undersurface hairs silver.
Shape and sculpture: Head: closely and shallowly punctured; median groove between eyes; narrow ridge inside each antennal cavity; muzzle short. Antennae: segments 1–3 obconic, 4–11 toothed. Pronotum: shallowly punctured; small median basal fovea extending forwards to middle as glabrous line; basal notch on either side closer to margin than to middle; projecting forwards in middle of apical margin; basal margin almost straight; laterally parallel-sided at base, rounded to apex, widest 1/3 distance from base. Scutellum: heart-shaped, with few punctures. Elytra punctate-striate, intervals convex and pitted with shallow punctures; laterally parallel-sided at base, angled outwards, rounded at shoulder then concave until after middle, rounded then tapered to pre-apical area, then rounded to apex which has no marginal spine, indented to suture which has minute spines; apices not diverging. Undersurface shallowly punctured, sparsely haired. Last visible abdominal segment truncate in males, rounded and narrowed in females.
Size: Males 14.1 ± 0.37 x 5.1 ± 0.19 mm (10). Females 14.6 ± 0.36 x 5.6 ± 0.13 mm (8).
Distribution: Western Australia and Victoria.
General remarks: The elytral pattern and colour are like those of *S. rubriventris* Blackburn. However, *S. hateleyi* is a smaller species, the male does not have a red abdomen and male genitalia is different. Named after Mr K. Hateley.

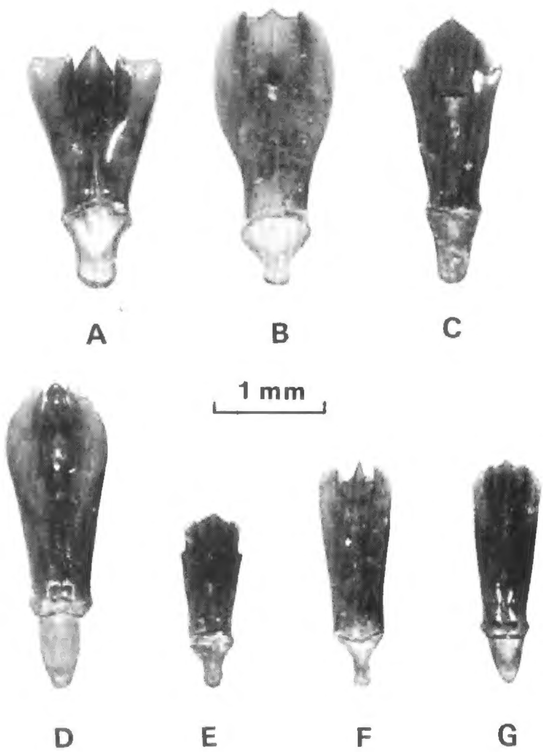

Fig. 3. Photomicrographs of male genitalia of *Stigmodera* (*Castiarina*) species: (A) *mimica*; (B) *hateleyi*; (C) *inflata*; (D) *aquila*; (E) *aliceae*; (F) *kiatae*; (G) *aurea*.

Stigmodera (Castiarina) inflata sp. nov.
FIGS 2C, 3C

Types: Holotype: ♂, Baker's Creek Falls, Armidale, N.S.W., 12.ii.1979, *T. J. Hawkeswood*, SAM I21, 110. Allotype: ♀, same data as holotype, SAM I21, 111. Paratypes: 6 ♂ & 13 ♀, Dangar Falls, Armidale, N.S.W., 22/23.ii.1978, *B. J. & T. J. Hawkeswood*, SAM; 18 ♂ & 3 ♀, same data as holotype, SAM; 1 ♂ & 4 ♀, Dangar Falls, Armidale, N.S.W., 10/14.ii.1979, *T. J. Hawkeswood*, SAM.

Colour: Head, antennae, scutellum, pronotum, undersurface and legs bronze. Elytra yellow with following black markings: anterior margin; pre-medial fascia expanded at outside ends into vittae reaching basal and lateral margins anteriorly and lateral margin posteriorly, enclosing basal yellow spot on each side and a spot on each shoulder; wide post-medial fascia reaching margin, concave in middle of each side anteriorly and posteriorly; mark covering whole apex; all marks connected down suture. Hairs silver.

Shape and sculpture: Head: with close shallow punctures; median groove between eyes; muzzle short. Antennae: segments 1–4 obconic, 5–11 toothed. Pronotum closely punctured; shallow median basal fovea projecting forwards to apex as median impressed line; anterior margin straight; basal margin bisinuate; laterally rounded from base, inflated in middle, rounded to apex. Scutellum: shield-shaped; concave in middle; with punctures. Elytra punctate-striate, intervals convex more so at base than apex; laterally angled out from base, rounded at shoulder, convex until after the middle then rounded and tapered to apex which is bispinose; marginal spine larger than sutural spine, rounded and indented between; apices slightly diverging. Undersurface with shallow punctures, covered in moderately long hair. Last visible abdominal segment subtruncate in male, rounded in female. Tarsal pads modified on feet of males: 1st leg, tarsal pads absent on segments 1 & 2, reduced on 3; 2nd leg, tarsal pad absent on segment 1, reduced on 2; 3rd leg, tarsal pad on segment 1 minute, reduced on 2 & 3; on each foot central spine present on undersurface of tarsal segments 1, 2 & 3 getting progressively smaller in that order.

Size: Males 10.9 ± 0.12 x 3.9 ± 0.04 mm (26), Females 11.7 ± 0.17 x 4.4 ± 0.09 mm (21).

Distribution: New England district, N.S.W.

General remarks: Close to *S. wilsoni* on similarities in male genitalia, but is larger than that species. The pronotum is more prominently inflated in the new species. In *S. wilsoni* the only shoulder marking is a single vitta on each side. In *S. inflata* the vittae are confluent with a pre-medial fascia. All specimens were collected on the flowers of *Bursaria spinosa*.

Stigmodera (Castiarina) aquila sp. nov.
FIGS 2D, 3D

Types: Holotype: ♂, Gleneagle, W. Aust., 15.i.1971, *K. T. Richards*, ANIC. Paratypes: 4 ♂, same data as holotype, SAM & WADA.

Colour: Head, antennae, pronotum, scutellum, undersurface and legs dull green. Elytra yellow with following black markings: anterior margin; pre-medial fascia projecting forwards to lateral margin from anterior end only; post-medial fascia reaching margin, projecting forwards on each side from near margin; pre-apical fascia not reaching margin; marks all connected down suture expanded at apex. Undersurface hairs silver.

Shape and sculpture: Head: closely punctured; median groove between eyes; muzzle short. Antennae: segments 1–3 obconic, 4 ½-toothed, 5–11 toothed. Protonum: with close punctures; median basal fovea; projecting forwards in middle of apical margin; basal margin barely bisinuate; laterally parallel-sided at base, rounded at apex, widest before the middle. Scutellum: heart-shaped; with punctures. Elytra: punctate-striate, intervals slightly wrinkled, convex at apex; laterally angled out from base, rounded at shoulder, faintly concave until after middle then rounded to apex which is bispinose; marginal spine larger than sutural, rounded and indented between; apices slightly diverging. Undersurface with close, shallow punctures; moderately hairy; hairs long. Last visible abdominal segment truncate in male.

Size: Males 11.0 ± 0.34 x 3.9 ± 0.19 mm (5).

Distribution: Darling Ranges, Western Australia.

General remarks: Male genitalia of this species show similarities to those of *S. scalaris*. However, *S. scalaris* has alternate intervals on the elytra slightly raised and the anterior margin of the pronotum is straight. Also the pre-medial fascia is represented by two spots on the shoulder. *S. scalaris* is found only in eastern Australia and neither species is represented in South Australia. All specimens were collected on *Astartea* sp.

Stigmodera (Castiarina) aliceae sp. nov.
FIGS 2E, 3E

Types: Holotype: ♂, Montacute, Mt Lofty Rgs, S. Aust., 3.xi.1963, *S. Barker,* SAM I21, 129. Allotype: ♀, same data as holotype, SAM I21, 130. Paratypes: 2 ♂, Murray Bridge, *Lea,* SAM; 1 ♂, Mt Lofty Rgs, 4.xii.1964, *N. McFarland,* SAM; 5 ♂ & 5 ♀, same data as holotype, SAM; 21 ♂ & 5 ♀, Athelstone, S. Aust., 22.x.1966, *McFarland & Newberry,* SAM; 1 ♂, Horsnell's Gully, 12.xi.1967, *S. Barker,* SAM; 2 ♂ & 2 ♀, Para Wirra N.P., S. Aust., 7.xi.1971, *S. Barker,* SAM; 3 ♂ & 1 ♀, Uraidla, S. Aust., 23/28.xii.1974, *A. Wells,* SAM; 1 ♂, Sommerton, S. Aust., SAM; 1 ♂, S. Aust., SAM.

Colour: Head, antennae, scutellum, undersurface and legs blue. Elytra yellow with following black markings with purple reflections: basal margin; pre-medial fascia expanded at outside ends into vittae reaching basal and lateral margins anteriorly and lateral margin posteriorly, enclosing basal yellow spot on each side and one on each shoulder; wide post-medial fascia reaching margin; mark covering whole apex; all marks connected down suture. Hairs silver.

Shape and sculpture: Head: closely punctured; median groove between eyes; muzzle short. Antennae: segments 1–4 obconic, 5–11 toothed. Pronotum: closely punctured; median basal fovea extending forwards as thin glabrous line almost to apex; basal notches on each side closer to margin than centre; projecting forwards in middle of apical margin, basal margin bisinuate; laterally parallel-sided at base then rounded to apex, widest before middle. Scutellum: heart-shaped; with punctures. Elytra: punctate-striate, intervals convex, more so at apex than base; laterally angled outwards from base, rounded at shoulder, concave until after middle, rounded to apex which is bispinose; both spines small, rounded and indented between; apices diverging slightly. Undersurface shallowly punctured; sparse very short hair. Last visible abdominal segment subtruncate in male, rounded in female. Tarsal pads modified on feet of male: tarsal pads absent on segments 1 & 2 on all feet, single central spine on undersurface of segments 1–3 on all feet in descending size from 1–3.

Size: Males 8.3 ± 0.1 x 2.9 ± 0.04 mm (38). Females 8.5 ± 0.22 x 3.0 ± 0.08 mm (14).
Distribution: South Australia.

General remarks: Close to *S. cruentata* (Kirby) on similarities in male genitalia. The two species differ in the pattern of reduction of tarsal pads in males. Named after Mrs A. Wells.

Stigmodera (Castiarina) kiatae sp. nov.
FIGS 2F, 3F

Types: Holotype: ♂, Kiata, Vic., xi.1967, *K. Hateley,* SAM I21, 131. Allotype: ♀, Kiata, Vic., xi.1967, *K. Hateley,* SAM I21, 132. Paratypes: 3 ♂, Big Desert, Vic., 17/19.xi.1977, *G. Burns,* GB; 2 ♂ & 2 ♀, same data as holotype, SAM; 1 ♂ & 1 ♀, Big Desert, Vic., 4.xi.1976, *G. Burns,* NMV & GB.

Colour: Head, pronotum, scutellum, undersurface and legs purple-bronze. Elytra yellow with following dark blue markings: anterior margin; vitta from outer edge of anterior margin running to lateral margin, enclosing elongate yellow mark on shoulder; rounded mark on suture remnant of pre-apical fascia; post-medial fascia expanded on suture and middle of each elytron not reaching lateral margin; apical mark covering whole apex, all marks connected along suture. Hairs silver.

Shape and sculpture: Head: closely punctured; median groove between eyes; muzzle short. Antennae: segments 1–3 obconic, 4–11 toothed. Pronotum closely punctured; small median basal fovea; anterior margin straight; basal margin barely bisinuate; laterally rounded from base, widest ⅓-distance to apex, slightly tapered to apex. Scutellum: heart-shaped; without punctures. Elytra punctate-striate, intervals flat at apex, more rounded at base; laterally slightly angled out from base, rounded at shoulder then concave until after middle, rounded and tapered to apex which is bispinose; apical spine large, sutural spine small, rounded and indented between; apices slightly diverging; sub-serrate lateral margin from post-medial region to apex. Undersurface with close shallow punctures, larger on pre-sternal sclerites than on abdomen; hairy, hairs moderately long. Last visible abdominal segment truncate in both sexes.

Size: Males 9.2 ± 0.20 x 3.3 ± 0.07 mm (7). Females 10.0 ± 0.21 x 3.6 ± 0.07 mm (4).

Distribution: Big and Little Desert areas, Victoria.

General remarks: This species is distinct from any other on the basis of male genitalia.

Stigmodera (Castiarina) aurea sp. nov.
FIGS 2G, 3G

Types: Holotype: ♂, 18 km E. of Maryborough, Qld, on *Leptospermum* sp., 5.xi.1975, *S. Barker,* SAM I21, 133. Allotype: ♀, same data as holo-

type, SAM I21, 134. Paratypes: 1 ♀, same data as holotype, SAM; 4 ♀, Maryborough, Qld, xi.1956, *E. Smith*, NMV; 1 ♂, Maryborough, 12.xii., *MJM*; ANIC; 1 ♂, Indooroopilly, 11.xi.1933, ANIC; 2 ♂, Wide Bay, Qld, AM; 1 ♂, Rockhampton, Qld, 10.i.1946, JH; 2 ♂ & 3 ♀, Qld, *du Boulay*, WAM.

Colour: Head, antennae, pronotum, scutellum black with olive-green reflections. Undersurface and legs olive green. Elytra yellow at basal end, apical end bright orange, with the following black markings: basal margin; short vitta on each shoulder reaching lateral and basal margins; basal elongate rounded mark on suture; post-medial fascia expanded on suture and close to margin, reaching margin; pre-apical fascia not reaching margin; mark covering apices; all marks connected down suture, the last two broadly. Hairs silver.

Shape and sculpture: Head with small shallow punctures; median groove between eyes; muzzle short. Antennae: segments 1–3 obconic, 4–11 toothed. Pronotum with small shallow punctures; basal fovea projecting forwards to middle as glabrous line; basal notch on each side closer to margin than to middle; anterior margin projecting forwards in middle; basal margin bisinuate; laterally rounded from base, gradually narrowing to apex, basal angles turned upwards. Scutellum: heart-shaped, sides folded inwards from centre; without punctures. Elytra punctate-striate, the intervals convex and smooth, the margin flattened; laterally angled out from base, rounded at shoulder, concave until after middle, rounded and narrowed to apex which is bispinose; marginal spine large, sutural spine very small, deeply indented between. Undersurface with close shallow punctures; moderately hairy, hairs medium length. Last visible abdominal segment, rounded and pushed in in middle in both sexes. Males have modified tarsal pads on 3rd leg, segments 1 & 2 have reduced pads, spines not present.

Size: Males 8.9 ± 0.9 x 3.2 ± 0.03 mm (9). Females 10.5 ± 0.09 x 3.9 ± 0.05 mm (9).

Distribution: South and central coastal Queensland.

General remarks: Close to *S. alternecostata* on the basis of similarities in male genitalia. However, *S. aurea* is a smaller species, the pronotum is continually narrowed from the base whereas in *S. alternecostata* the pronotum is widest before the middle. Sculpture and colour pattern of the elytra also differ.

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SOME STRONGYLE NEMATODES (AMIDOSTOMUM SPP.) FROM AUSTRALIAN BIRDS

BY PATRICIA M. MAWSON

Summary

Amidostomum acutum is recorded from Anas superciliosa, A. platyrhynchos, Stictonetta naevosa, Querquedula gibberifrons, Tadorna radjah and Himantopus leucocephalus, A. anseris from Cereopis novaehollandiae; A. cygni from Cygnis atratus; A. biziurae from Biziaura lobata. Measurements of most specimens examined and morphological notes on A. cygni and A. biziurae are given. A new species, A. tribonyx, close to A. acutum, but distinguished by shorter spicules and very large papillae, is described from Tribonyx ventralis.

SOME STRONGYLE NEMATODES (*AMIDOSTOMUM* SPP.) FROM AUSTRALIAN BIRDS

by PATRICIA M. MAWSON*

Summary

MAWSON, P. M. (1980) Some strongyle nematodes (*Amidostomum* spp.) from Australian birds. *Trans. R. Soc. S. Aust.* 104(1), 9-12, 29 February, 1980.

Amidostomum acutum is recorded from *Anas superciliosa, A. platyrhynchos, Stictonetta naevosa Querquedula gibberifrons, Tadorna radjah* and *Himantopus leucocephalus. A. anseris* from *Cereopsis novaehollandiae; A. cygni* from *Cygnus atratus; A. biziurae* from *Biziura lobata.* Measurements of most specimens examined and morphological notes on *A. cygni* and *A. biziurae* are given. A new species, *A. tribonyx*, close to *A. acutum*, but distinguished by shorter spicules and very large cervical papillae, is described from *Tribonyx ventralis.*

Introduction

Nematodes of the genus *Amidostomum* appear to be restricted to waterfowl; almost all records are from anseriform and ralliform birds, and a few from charadriform birds. The genus was studied in some detail by Czaplinski (1962). Of the 16 species then recorded, he synonymised 11. Four species have been described subsequently.

In the present work three of the species recognised by Czaplinski are identified from Australian birds, one species he considered a synonym is resurrected and a new species is described.

Measurements of specimens examined are tabulated, but those indicating the position of nerve ring, cervical papillae and excretory pore are omitted in some cases. These structures, especially the first two, are particularly obscure in some species. The new species is noteworthy because of the unusually large cervical papillae.

Types of the new species will be deposited in the South Australian Museum, and all other material belongs to the Australian Helminthological Collection at present in the South Australian Museum.

Amidostomum acutum (Lundahl)

Strongylus acutus Lundahl, 1848.
Hosts and localities: Anas superciliosus Gmelin: Hamley Bridge S.A. (2 ♂), Westbury, Tas. (24 ♂, 18 ♀); *A. platyrhynchos*, Flinders I., Tas. (1 ♂, 1 ♀); *Stictonetta naevosa* (Gould), Bool Lagoon, S.A. (2 ♂); *Querquedula gibberifrons* S. Müller, Naracoorte, S.A. (1 ♂); *Querquedula* sp., Adelaide, S.A. (1 ♂); *Tadorna radjah* Garnot, Humpty Doo, N.T. (1 ♂); *Himantopus leucocephalus* Gould, Petermann Ra., N.T. (1 ♂, 2 ♀).

In his work on *Amidostomum*, Czaplinski (1962) gives a good account of *A. acutum*, and referred a number of species to its synonymy. Except for *A. biziurae* Johnston & Mawson, this synonymy has been adopted here. Reasons for this exception are given in the account of *A. biziurae*.

Measurements of specimens from *Anas superciliosus*, which are most numerous and in good condition, are given in Table 1.

Amidostomum anseris (Zeder)

FIG. 2

Strongylus anseris Zeder, 1800.
Host and locality: Cereopsis novaehollandiae Latham, from Flinders I., Tas. (5 ♂, 7 ♀).

These specimens agree generally with the description, figures and measurements given by Czaplinski in his summary of the species. The only (and slight) difference is that the anterior lip of the vulva, and in two specimens both anterior and posterior lips, are enlarged (Fig. 2). Czaplinski describes this region as "vulva provided with conspicuous hemispherical bulge". Measurements of these specimens are given in Table 1.

Amidostomum biziurae Johnston & Mawson

FIG. 1

Amidostomum biziurae Johnston & Mawson, 1947.
Host and localities: Biziura lobata (Shaw) from Goolwa, S.A. (3 ♂, 2 ♀), Barren Box Swamp, N.S.W. (5 ♂, 5 ♀).

This species, originally described from one female, was redescribed from new material of both sexes (Mawson 1959). The specimens recorded here from the type host species and new localities agree with this description.

Czaplinski (1962) placed *A. biziurae* in the synonymy of *A. acutum*, apparently not having seen this redescription. However, he discounted the projections around the mouth,

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TABLE 1. *Measurements of* Amidostomum *spp. recorded here (µm unless otherwise stated).*

Species	*A. acutum*		*A. cygni*	*A. anseris*	*A. tribonyx*
Host	*Anas superciliosus*	*Himantopus leucocephalus*	*Cygnus atrata*	*Cereopsis novaehollandiae*	*Tribonyx ventralis*
Male (number)	(5)	(1)	(2)	(4)	(3)
Length (mm)	9.2–11.4	7.2	15–17	12.3–15.5	7.6–9.7
Oesophagus	640–760		1280–1500	1450	650–856
rods occupy			90–95%	99%	81–84%
A—nr	250–300		350–400	260–280	240–250
—cp	360–410		520–600	350–400	280–350
—exp	300–420		520–600	320–340	–
spicules	130–140	140	190–200	280–312	100–110
gubernaculum	60–70	80	105–110	110–115	30
bucc. caps: length	9	8	12–13	15–16	10
ext. diameter	11–12	13	35	31–35	18–19
Female (number)	(5)	(2)	(2)	(4)	(3)
Length (mm)	13.5–17.0	13.6–13.7	22.0–22.1	19.5–21.0	7.6–10.0
Oesophagus	760–850		1250–1550	1420–1650	650–730
rods occupy			96%	99%	84–86%
A—nr	250–300		350–390	350–390	210–240
—cp	300–400		500–550	500–550	300–310
—exp	300–490		500–505	505–550	–
bucc. caps: length	10–11	9	15–16	15–16	10–12
ext. diameter	12–16	17–18	36–40	36–41	18–22
tail	250–280	250–260	250–260	240–330	220–300
vulva–posterior end (mm)	2.4–2.8	2.7–2.8	3.8–3.9	2.7–3.1	1.8–2.5
eggs–L	80–90	91–95	89–90	90–95	90–95
–Br	50–51	42–45	50–51	45–55	50–52

regarded by the authors as one of the main specific characters, as being enlarged labial papillae. In fact these are not labial papillae, but cuticular structures, containing no nerve or other hypodermal tissue. The four labial papillae and two amphids are seen behind the projections (Mawson 1959, figs 4-5). The projections are obvious on all specimens, and arise in association with the anterior edge of the buccal capsule.

The other striking feature of the species is the embossed cuticular annules, which appear on all specimens, and have not been seen in any other species. A more detailed figure is given of the spicules.

Amidostomum cygni Wehr

FIGS 3–5

Amidostomum cygni Wehr, 1933.

Host and locality: Cygnus atratus Latham, Adelaide, S.A. (13 ♂, 16 ♀).

This species was recorded from *C. atratus* (syn. *Chenopis atrata*) from Tailem Bend, S.A. by Johnston & Mawson (1947), but that material did not include the posterior end of a male. The present material is more plentiful and a closer study has been made.

The measurements (Table 1) are generally larger than those given by Wehr (1933) or by Ryzhikov (1959). Czaplinski (1962) regards *A. similis* Freitas & Mendonca (1954) from a South American swan a synonym of *A. cygni*: the only difference being in the greater size and in that the authors noted three instead of two (Ryzhikov) branches to each spicule. Wehr simply states that the spicule is "similar in shape to those of other species of the genus". In the Australian specimens there are three branches, one much shorter and thinner, the other two lying close together except at the tips where one ends bluntly, the other is splayed out. In the expanded state all branches support a membranous structure which appears to be globular rather than fan-shaped (Fig. 4).

Amidostomum tribonyx sp. nov.

FIGS 6–10

Host and localities: Tribonyx ventralis Gould, from Swan Reach (3 ♂, 3 ♀), and Taperoo (1 ♂, 1 ♀), S.A.

Holotype male, SAM, V1864. Allotype female, SAM, V1865.

Lateral alae absent, buccal capsule stoutly built, with single, dorsal tooth reaching almost to anterior edge of buccal capsule. Oesophagus widens slightly posteriorly. Cervical papillae prominent cuticular projections.

Male: Spicules bifid, each branch alate, rounded at distal end, the more ventral branch

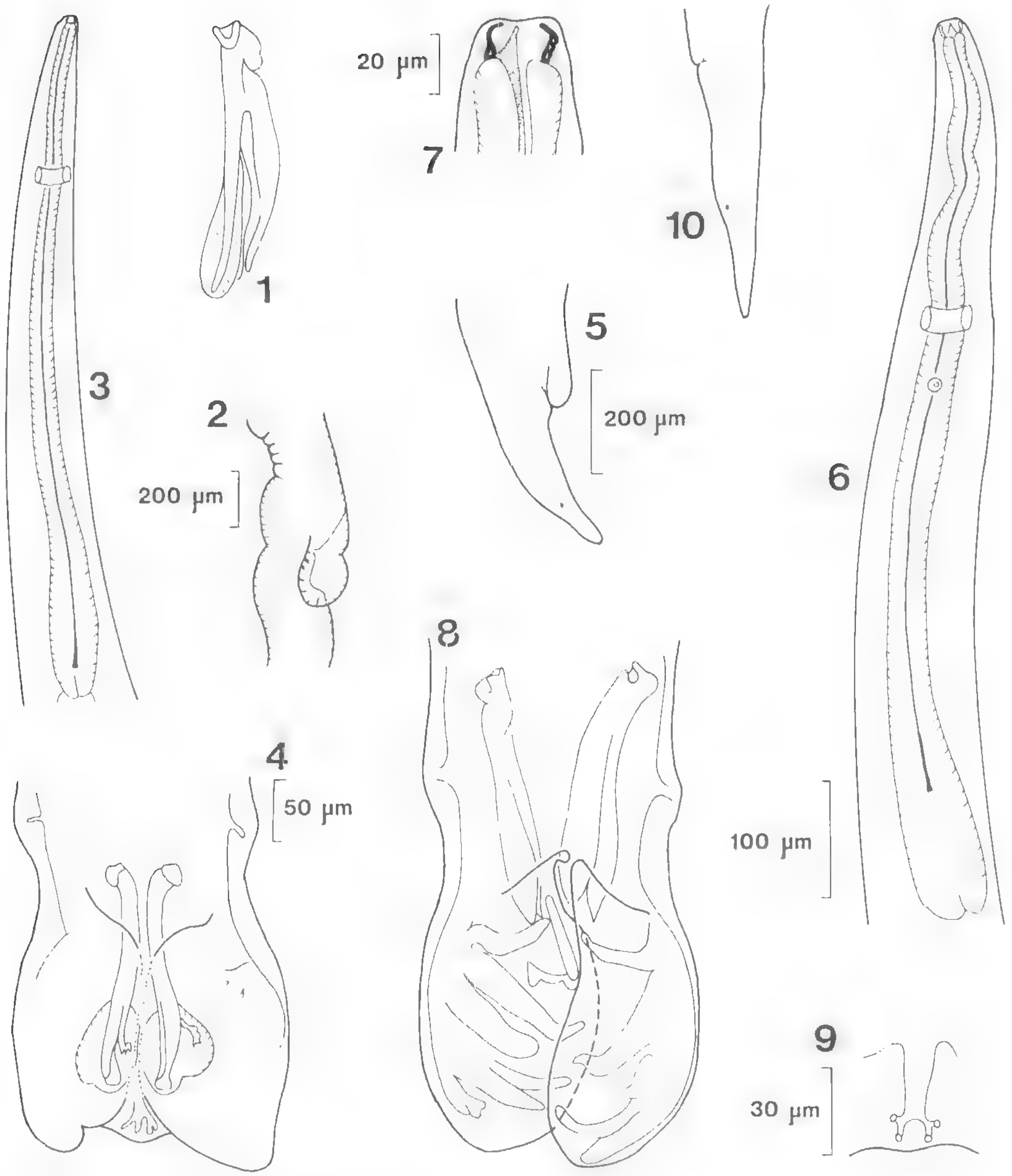

Fig. 1. *Amidostomum biziurae,* spicule.
Fig. 2. *A. anseris,* vulvar region.
Figs 3-5. *A. cygni.* Fig. 3, anterior end; Fig. 4, posterior end showing spicules partly everted; Fig. 5, posterior end of female.
Figs 6-10. *A. tribonyx.* Fig. 6, anterior end; Fig. 7, head; Fig. 8, bursa, ventral view; Fig. 9, dorsal ray; Fig. 10, posterior end of female.
Figs. 1, 8 & 9 to same scale; Figs 3 & 5 to same scale; Figs 4 & 10 to same scale.

slightly longer. Gubernaculum poorly sclerotized, about ¼ length of spicules. Bursal rays typical of genus(Figs 8 & 9).

Female: Tail widens about midlength, at level of phasmids, then narrows to rounded tip. Vulva at about ¼ body length from posterior end, with swollen anterior lip.

This species differs from *A. acutum* in the smaller spicules and gubernaculum, and from all congeners by the large cervical papillae. Measurements are included in Table 1.

Acknowledgments

The birds from which the material used in this work were obtained were sent to me by Mr H. Frith (C.S.I.R.O., Canberra), the Northern Territory Museum, the South Australian Museum, and Mr R. Green (Victoria Museum, Tasmania).

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CIRCULAR STRUCTURES IN A LATE PRECAMBRIAN SANDSTONE: FOSSIL MEDUSOIDS OR EVIDENCE OF FLUIDIZATION?

BY P. S. PLUMMER

Summary

Small circular structures have been found preserved on the basal surface of a Late Precambrian sandstone within the Moorillah Formation in the Flinders Ranges, South Australia. Although their mode of preservation and general appearance suggest a biogenic origin, it is believed that a non-biogenic process involving gas migration and sediment fluidization was responsible for their formation.

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by P. S. PLUMMER*

Summary

PLUMMER, P. S. (1980) Circular structures in a Late Precambrian sandstone: Fossil medusoids or evidence of fluidization *Trans. R. Soc. S. Aust.* **104** (1), 13-16, 29 February, 1980.

Small circular structures have been found preserved on the basal surface of a Late Precambrian sandstone within the Moorillah Formation in the Flinders Ranges, South Australia. Although their mode of preservation and general appearance suggest a biogenic origin, it is believed that a non-biogenic process involving gas migration and sediment fluidization was responsible for their formation.

Introduction

Recently found within the central Flinders Ranges of South Australia was a float sample[1] of ripple cross-laminated fine sandstone on the basal surface of which are preserved a number of small, roughly circular structures of problematic origin. The sample was collected about 10 km southeast of Wilpena Chalet (lat. 31°36'S, long. 138°40'E) near the contact between the Moorillah Formation and the underlying Moolooloo Formation of the Late Precambrian Brachina Subgroup (Plummer 1978). Its lithology is typical of the lower portion of the Moorillah Formation and, although the sample is from float, it is considered to have come from this horizon.

A possible biogenic origin for these structures is suggested if their mode of preservation (i.e. on the basal surface of a sandstone lying directly above a clay layer) is compared with that of the many soft-bodied animal fossils found within the Late Precambrian Ediacara assemblage (see Wade 1968). This, along with their overall circular shape and concentric rings marking their perimeters, suggests a resemblance to small medusoid fossils. If this were so, they would form perhaps the oldest fossil coelenterate occurrence known, lying 2500 m below the level of the Ediacara assemblage, and well beneath the presently known oldest occurrence in the Bonney Sandstone (formerly the "Red Pound") of the Pound Subgroup where small medusoids are found in association with sinuous tracks (Wade 1970).

Description

The basal surface of the sample measures 16 x 11 cm and shows several roughly circular structures which range 6–20 mm in diameter with relief up to 2 mm (Fig. 1a). The centres of these structures are generally shallowly domed (Fig. 1b), although some are flat, or display a central depression (Fig. 1c). Poorly defined step-like concentric rings are present toward the edges of some of the structures (see Fig. 1b), whilst surrounding them is the suggestion of a flat skirting rim up to 8 mm wide. Shaly material is patchily preserved on this basal surface of the sample, indicating that the ripple cross-laminated sand formed casts of these structures which were developed in, or present on an underlying clay bed.

Interpretation

These structures are comparable to the fossil medusoids classed as *Protolyella* Torell 1870, which includes the taxon *Medusina* Sprigg 1949. *Protolyella* is represented by circular bodies up to 5 cm diameter, comprising a smooth central area and an outer annular zone, separated by an annular furrow (Moore 1956; Glaessner & Wade 1966). Although the central area of these fossils can show faint concentric markings, the outer annular zone usually displays numerous radial grooves not present on the structures described herein.

Other widely distributed circular organic structures of Late Precambrian age are the planktonic remains known as *Chuaria* Walcott 1899. These fossils, however, are usually preserved as black, discoidal compressions, commonly carbonaceous, and having a maximum diameter of 5 mm (Hofmann 1977). As such, the structures described here are too large and of the wrong style of preservation to be *Chuaria*.

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[1] Sample in Department of Geology, University of Adelaide: cat. No. 469/EPB110.

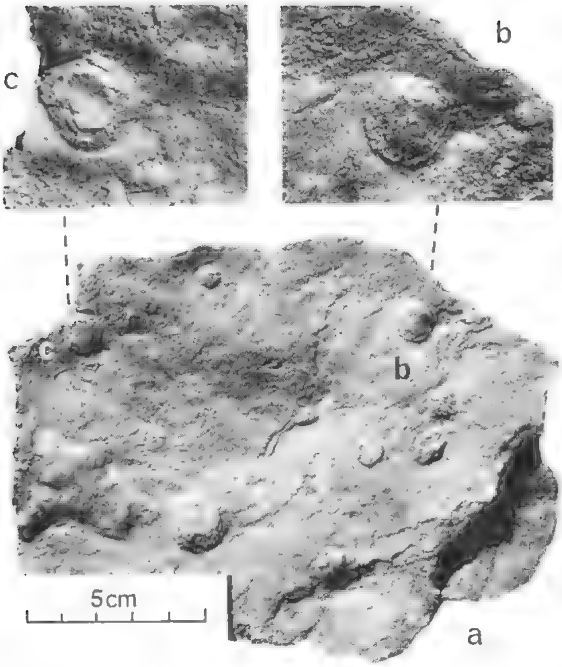

Fig. 1. Circular structures. (a) casts on basal surface of sample; (b) shallowly domed centre; (c) central depression.

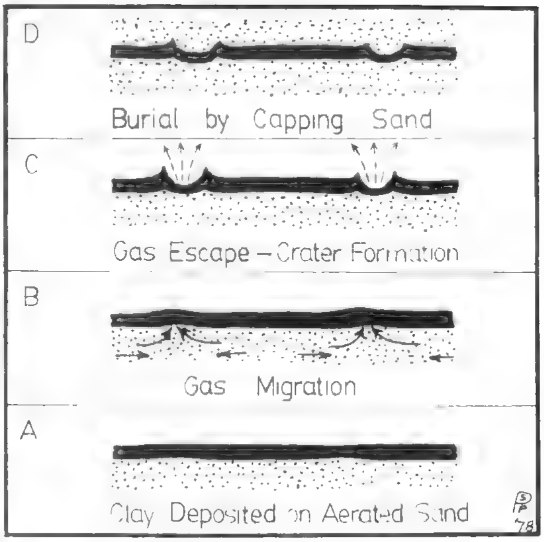

Fig. 2. Schematic diagram of crater formation by 'cold' fluidization process.

Maxson (1940) and Cloud (1960) have interpreted structures comparable to those under discussion in terms of gas escape and fluidization phenomena. Such phenomena are well known to igneous geologists (e.g. Reynolds 1954; Holmes 1965), but their influence upon sedimentation has been little discussed. Mills (1969), however, gives an excellent account of structures formed experimentally by 'cold' fluidization which closely resemble the structures discussed herein. Although his experiments were concerned with the origin of craters on the lunar surface, the phenomenon of 'cold' fluidization is equally applicable to much smaller scale structures.

The process of 'cold' fluidization involves the migration to the surface of gas trapped within a stationary bed. In a cohesive sediment, such as a clay, gas migration can cause the bed to expand and display the flow properties of a liquid. Often the gas flow finds preferred channels of escape and, if the flow is great enough, bubbles may form in the channels. On reaching the surface the bubbles either burst, or dissipate gently (depending on the degree of bed cohesion) causing the bed to then contract and subside. Ring slumping and faulting often accompanies the subsidence, and the net result is the production of circular, crater-like structures.

Such a process could have operated to produce the structures found on the sample described here. Sedimentologic analysis has indicated that the Moorillah Formation was deposited dominantly within an intertidal environment (Plummer 1978). During a period of low tide, gas or air trapped within sandy sediment could have migrated upward through a capping clay layer (possibly deposited during the slack-water stage of the previous high tide) to burst and form small craters on the surface. Gas escape phenomena are known to occur on present-day intertidal flats (Reineck & Singh 1975, Fig. 61), and the burial of such craters by a layer of sand during the following incoming tide could then preserve them as casts on its basal surface (Fig. 2). Such gas produced structures have been called 'evasion marks' by Cloud (1960), who differentiated them from 'contact marks' produced by single, or numerous gas bubbles blown across the sediment surface; raindrop impressions (Lyell 1851, Shrock 1948); and other 'pit-and-mound' structures produced by compaction-induced dewatering (Kindle 1916, Schofield & Keen 1929), or current flow stress (Karcz *et al.* 1974).

Other organic structures?

Also reported from the Moorillah Formation are other structures which were initially

believed to be of organic origin. The solitary trace-like marking *Bunyerichnus dalgarnoi* Glaessner 1969 was described as the track of an animal possibly "related to primitive mollusca without mineralized shells" (Glaessner 1969, p. 379). However, Jenkins (1975, p. 19) regarded it "a unique and accidental set of markings made by a tethered implement being moved by a current" (e.g. possibly ribbon-like algae such as are known from rocks of similar age in the U.S.S.R.). A close resemblance is also noted between this marking and certain lineations produced by vorticity along lines of wind flow (Whitney 1978, Fig. 4B). Also, abundant cylindrical to conical structures occur in this formation that resemble either certain fossil burrows or other problematic Precambrian sack-shaped fossil organisms such as *Namalia* Germs 1968, the 'Ernietlomorpha' of Pflug (1972) and *Baikalina* Sokolov 1972. These structures, however, are pot-casts produced by the helical scouring action of water currents (Jenkins *et al.* in prep.).

Conclusion

Of the two possible origins presented to explain the structures discussed herein (*viz.* the fossilization of small medusoids, or gas escape and 'cold' fluidization phenomena) the latter, non-biogenic origin is favoured. Similarly, other circular structures found in deposits of Precambrian age that have previously been described as problematica or organic remains (e.g. Bassler 1941, Alf 1959, Shepherd & Thatcher 1959, Johnson & Fox 1968) should be reviewed in terms of formation by fluidization phenomena, or other inorganic processes (as suggested by Cloud 1960, 1973).

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Dr R. J. F. Jenkins provided much discussion on Precambrian life forms and traces, whilst both he and Dr V. A. Gostin critically read the manuscript.

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SYSTEMATIC STATUS OF KANKANOPHRYNE HEYER & LIEM (ANURA: LEPTODACTYLIDAE)

BY M. J. TYLER & MARGARET DAVIES

Summary

The diagnostic characters of Kankanophryne Heyer & Liem (1976) that distinguish it from the Pseudophryne Fitzinger (1843) were stated to be in the form of the sacral diapophyses and the number of slips of the Musculus depressor mandibulae. Our survey of these features in the two genera fails to support any distinction; hence we propose that Kankanophryne be referred to the synonymy of Pseudophryne.

SYSTEMATIC STATUS OF *KANKANOPHRYNE* HEYER & LIEM (ANURA: LEPTODACTYLIDAE)

by M. J. TYLER & MARGARET DAVIES*

Summary

TYLER, M. J. & DAVIES, M. (1980) Systematic status of *Kankanophryne* Heyer & Liem (Anura: Leptodactylidae). *Trans. R. Soc. S. Aust.* **104**(1), 17-20, 29 February, 1980.

The diagnostic characters of *Kankanophryne* Heyer & Liem (1976) that distinguish it from *Pseudophryne* Fitzinger (1843) were stated to be the form of the sacral diapophyses and the number of slips of the Musculus depressor mandibulae. Our survey of these features in the two genera fails to support any distinction; hence we propose that *Kankanophryne* be referred to the synonymy of *Pseudophryne*.

Introduction

Heyer & Liem (1976) undertook an analysis of intergeneric relationships in Australian myobatrachid (leptodactylid) frogs. Amongst their consequent proposals was the erection of the genus *Kankanophryne* for *Pseudophryne occidentalis* Parker, described from Western Australia (Parker 1940) and reported from South Australia by Tyler (1972). The rationale for Heyer & Liem's action was the stated existence in *P. occidentalis* of a small series of character states not shared by congeners. The authors stated that these were "differences best reflected at the generic level" (1976, p. 5).

Tyler (1978) failed to adopt the new generic name, but Cogger (1978) has included *Kankanophryne* in the revised edition of his "Reptiles and Amphibians of Australia". Because our observations on the definitive characteristics involved are at variance with those published by Heyer & Liem, we present these data here to clarify the systematic status of *Kankanophryne*.

Our retention of the name Leptodactylidae instead of adopting Myobatrachidae reflects the absence of morphological substantiation for the latter step. This matter is discussed in detail by Tyler (1979).

Material and Methods

We have examined the external features, myology and osteology of representatives of the following species: *Pseudophryne bibroni* Günther, *P. coriacea* Keferstein, *P. guentheri* Boulenger, *P. occidentalis* and *P. semimarmorata* Lucas. Specimens are deposited in the collections of the South Australian Museum (SAM), Western Australian Museum (WAM) and Department of Zoology, University of Adelaide (UAZ).

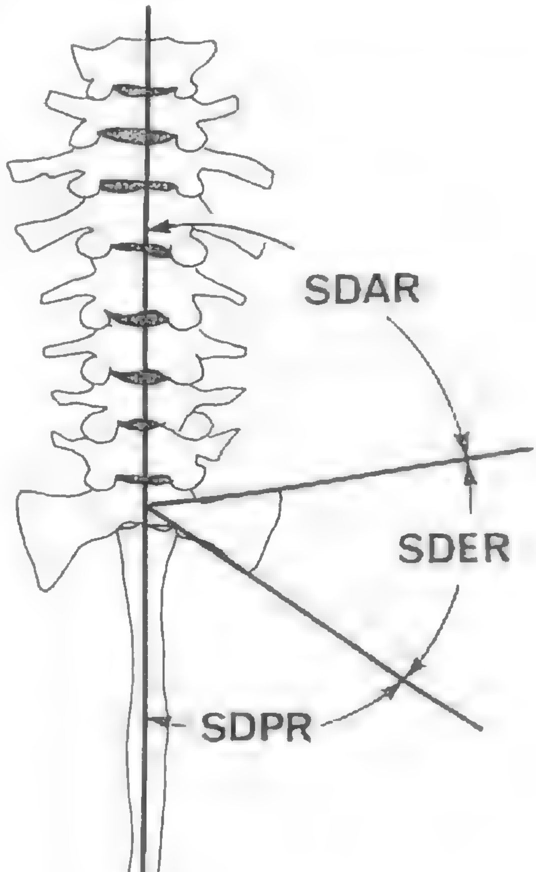

Fig. 1. Angles of sacral diapophyses measured. SDAR: anterior angle of right sacral diapophysis; SDER: greatest expansion of right sacral diapophysis; SDPR: posterior angle of right sacral diapophysis.

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Muscles were examined with the aid of the iodine/potassium iodide stain developed by Bock & Shear (1972). Bones and cartilage were examined employing either cleared and Alizarin Red staining or the differential Alizarin Red/Alcian Blue stain (Davis & Gore 1947; Dingerkus & Uhler 1977). The method of measurement of sacral diapophyseal angles follows Trueb (1977) and is demonstrated in Fig. 1.

Generic diagnoses

Heyer & Liem's diagnoses of *Pseudophryne* Fitzinger and *Kankanophryne* are identical in the condition of the following features: separation of cervical cotyles, lack of Musculus omohyoideus, lack of columella, texture of belly skin, form of toes, presence of metatarsal tubercle and mode of reproduction.

The diagnoses differ in the following respects:

Vomerine bones. Present or absent in *Pseudophryne;* absent in *Kankanophryne.*

Sacral diapophyses: Broad in *Pseudophryne;* narrow in *Kankanophryne.*

Depressor mandibulae: Slip from dorsal fascia absent in *Pseudophryne;* present in *Kankanophryne.*

It follows that the critical characteristics for the recognition of *Kankanophryne* are the conditions of the sacral diapophyses and depressor mandibulae.

Expansion of sacral diapophyses

The definition of character state 12 in Heyer & Liem's paper is as follows: State 0: sacral diapophyses expanded; State 1: sacral diapophyses rounded uniformly, in at least some species. They then proceed to score *P. occidentalis* as State 1 and the remaining species of *Pseudophryne* as State 0. Generic descriptions of *Kankanophryne* and *Pseudophryne* refer to "narrow" and "broad" sacral diapophyses respectively.

The majority of anurans have moderately expanded sacral diapophyses (designated "dilated" by Trueb (1973)). Amongst the Ranidae, however, the sacral diapophyses are narrow and usually directed posterolaterally whereas at the other extreme of the spectrum (in the Bufonidae), sacral diapophyses are very broadly expanded. Lynch (1971) considered that any distinction between the degree of dilation of the sacral diapophyses exhibited by some of the Australopapuan leptodactylid genera he examined, is a very fine one and probably is not defensible. Trueb's (1977) investigation into the osteology of a population of *Hyla lanciformis* (Cope) indicated that a degree of uncertainty exists about the reliability of vertebral characters. Vertebral anomalies are common amongst anurans, particularly in the form of bilateral asymmetry, and presence of additional features such as transverse processes on the coccyx in some individuals (unpublished observations). Trueb (1977) observed that a low coefficient of variability in the shape and orientation of the anterior edge of the sacral diapophyses occurred in her study population, indicating that some sacral features are reliable for systematic purposes.

We have carried out Trueb's measurements on the species examined by us and the results are shown in Table 1. The vertebral columns

TABLE 1. *Measurements of sacral diapophyses (see Fig. 1) in individuals of* Pseudophryne *and* Kankanophryne.

Species	Sacral angle measurement in degrees					
	SDAL	SDAR	SDEL	SDER	SDPL	SDPR
P. bibroni	83.5	75.0	41.0	49.5	55.5	55.5
P. coriacea	68.5	72.0	49.0	39.5	62.5	68.5
P. guentheri	82.5	85.5	50.0	39.0	47.5	55.5
P. semimarmorata	69.5	74.5	53.5	43.0	57.0	62.5
K. occidentalis	80.0	78.5	49.0	52.5	51.0	49.0

SDAL(R): Anterior angle of left (right) sacral diapophysis; SDEL(R): Greatest expansion of left (right) sacral diapophysis; SDPL(R): Posterior angle of left (right) sacral diapophysis.

of the species considered are shown in Fig. 2. Whilst recognising that the measurements in Table 1 have been made on individuals rather than populations, it can be seen that there is no significant difference in the expansion of the sacral diapophyses between *P. occidentalis* and the other species of *Pseudophryne* examined by us. We can find no justification for Heyer and Liem scoring the expansion of the sacral diapophyses in *P. occidentalis* as "narrow" in comparison with other *Pseudophryne.*

Depressor mandibulae

Griffiths (1954, 1959) demonstrated the existence of interspecific divergence in the form of the M. depressor mandibulae, and the way in which this divergence could be employed for systematic purposes. Griffiths

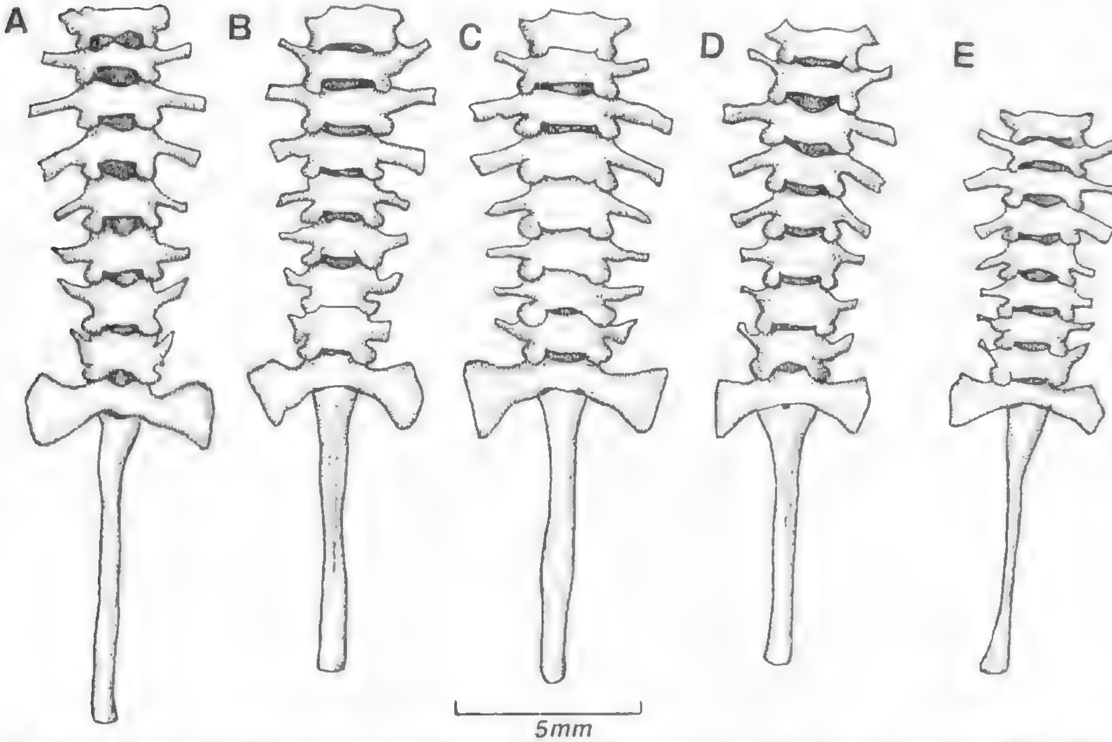

Fig. 2. Vertebral columns of (A) *Pseudophryne semimarmorata* UAZ B536, Koonwarra, Vic., (B) *P. occidentalis*, SAM R17522, approx. 100 km S of Balladonia Hotel, W.A. (33°13'S, 123°27'E); (C) *P. guentheri*, UAZ B539, Forrestfield, W.A.; (D) *P. bibroni*, UAZ A577, Tandanya Farm, Kangaroo Is.; (E) *P. coriacea*, UAZ B537, Conondale Ra., Qld. Note similarity of shape of sacral diapophyses and the numerous examples of vertebral bilateral asymmetry.

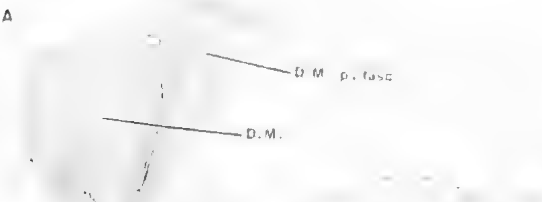

Fig. 3. Lateral view of Depressor mandibulae muscles. A: *Pseudophryne semimarmorata*; B: *P. bibroni*; C: *P. occidentalis*. A slip of the muscle occurs upon the dorsal fascia in each species. D.M.: main squamosal/otic element of depressor mandibulae; D.M.p.fasc.: depressor mandibulae pars fascialis; D.M.p.tymp.: depressor mandibulae pars tympanicus.

recognised three conditions in the origin of this muscle: (a) arising from the posterior border of the otic arm of the squamosal, (b) arising from the squamosal and the dorsal fascia and, (c) arising from the dorsal fascia alone.

In some respects this descriptive system represents a simplification because the muscle commonly comprises three elements: the third arising from the tympanum and termed the "pars tympanicus".

Lynch (1971) examined the condition of the depressor mandibulae in *P. bibroni* and *P. corroboree* and reported that the genus has only one slip — the pars tympanicus.

Our studies do not support the observations of Lynch or those of Heyer & Liem. As illustrated in Fig. 3, each of the species examined by us has large squamosal and dorsal fascial elements. The relative size of the dorsal fascia element in *P. occidentalis* is intermediate between that exhibited by *P. bibroni* and that in the type species *P. semimarmorata*. In *P. guentheri* the M. depressor mandibulae resembles the condition in *P. bibroni* except that the slip to the dorsal fascia is slightly smaller.

Discussion

Our observations indicate that the form of the M. depressor mandibulae and sacral diapophyses of *P. occidentalis* cannot be distinguished from the condition exhibited by the type species of *Pseudophryne* (*P. semimarmorata*). *Kankanophryne* was erected on the premise that the species differed substantially from *Pseudophryne*, but we are unable to support its maintenance, and we propose that *Kankanophryne* be referred to the synonymy of *Pseudophryne*.

Acknowledgments

This study was supported by a grant to M.J.T. by the Australian Research Grants Committee.

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NEW RECORDS OF KOONUNGA CURSOR SAYCE, 1908 (SYNCARIDA, ANASPIDACEA)

BY P. DE DECKKER

Summary

Koonunga cursor is recorded from two new localities, one in southwest Victoria and the other in northwest Tasmania. Specimens are illustrated with scanning electron microphotographs and drawings of the appendages.

NEW RECORDS OF *KOONUNGA CURSOR* SAYCE, 1908 (SYNCARIDA, ANASPIDACEA)

by P. De Deckker*

Summary

De Deckker, P. (1980) New records of *Koonunga cursor* Sayce, 1908 (Syncarida, Anaspidacea). *Trans. R. Soc. S. Aust.* 104(2), 21-25, 29 February, 1980.

Koonunga cursor is recorded from two new localities, one in southwest Victoria and the other in northwest Tasmania. Specimens are illustrated with scanning electron microphotographs and drawings of the appendages.

Introduction

Most parts of South Australia are too arid for anaspidacean syncarid crustaceans to live—permanent, natural freshwater bodies are rare except in the southeast near Mt Gambier where rainfall is highest. However, in Victoria very close to the S.A. border near Mt Gambier the living syncarid *Koonunga cursor* has recently been found and is described here.

Discussion

Sayce (1908) described *K. cursor* from "freshwater reedy pools beside a tiny runnel joining the Mullum Mullum Creek at Ringwood near Melbourne". Drummond (1959) stated that J. Searle in 1930 failed to find *K. cursor* in the type locality because it had become a storm-water drain. However, in an introductory account of crustaceans from Victoria, Morrison (1955) mentioned that "*Koonunga* . . . had been extensively collected by various members of the Zoology Department of Melbourne University . . .". She also stated that "it now appears that the Koonungidae are widely distributed, with local abundance, in an area south of the Great Dividing Range extending from Portland to Wilson's Promontory". Unfortunately no localities were mentioned by Morrison. Drummond's (1959) short note on the Australian syncarids said that "*Koonunga* [is] . . . now known to occur sporadically right across the southern part of Victoria". Nevertheless, he made no reference to particular localities and none have since been reported. Even Schminke's (1978) paper, which included an illustration of the telson of a juvenile specimen of *K. cursor* given him by F. H. Drummond, gave no locality data.

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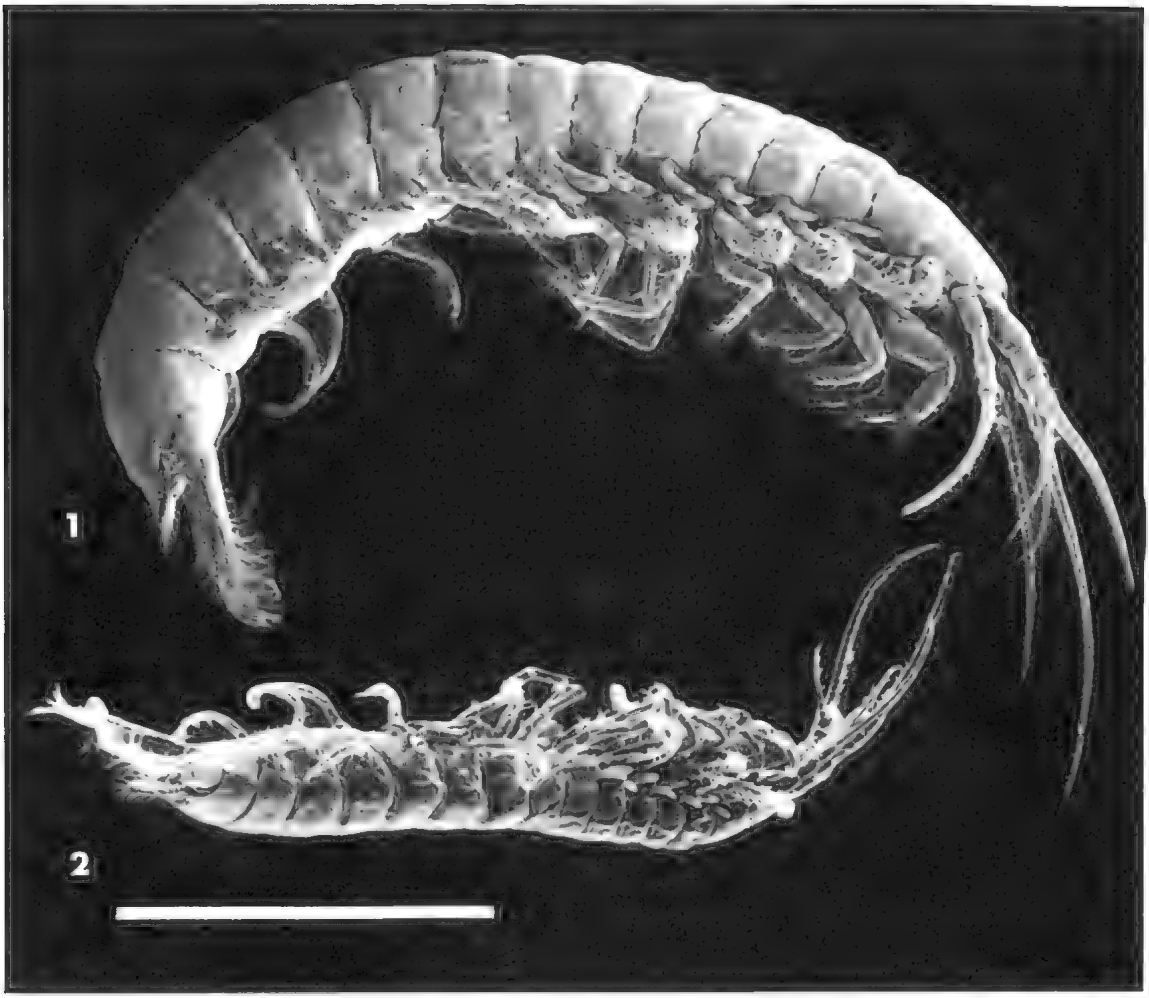
Recently *K. cursor* has been collected from the following localities: (1) Victoria, close to the S.A. border, under the footbridge over the rivulet at Bullocky Wells Picnic Area, 1.5 km E. of Greenwald on the main road between Mt Gambier and Heywood (35°58'42"S, 141°23'09"E) 24. v. 1979; (2) northwestern Tasmania, from Mowbray Swamp near Mella, 5 km W. of Smithton. This Tasmanian record is the first to be published, although P. S. Lake (*in* Williams in press) has informally reported its occurrence there. No locality data were given. At the Victorian locality, 15 females and seven males were collected from floating vegetation. The females were larger and darker in colour than the males. Adult males were easily recognized by the peculiar globular organ attached to the antennule (Fig. 4, 9). The largest female collected was 9.4 mm long (anterior tip of head to base of telson) and the largest male, 5 mm long. In Tasmania, several specimens were collected, but only one, a female 7.8 mm long, could be examined after preservation.

An undissected female and male are illustrated in Figs 1-2, and particular features of their anatomy are shown in more detail in Figs 3-8. To broaden Sayce's (1908) description, the left appendages of one male specimen from locality (1) were dissected (Figs 9-34). These specimens are deposited in the Australian Museum, Sydney, with two undissected specimens of each sex accompanied by the Tasmanian specimen.

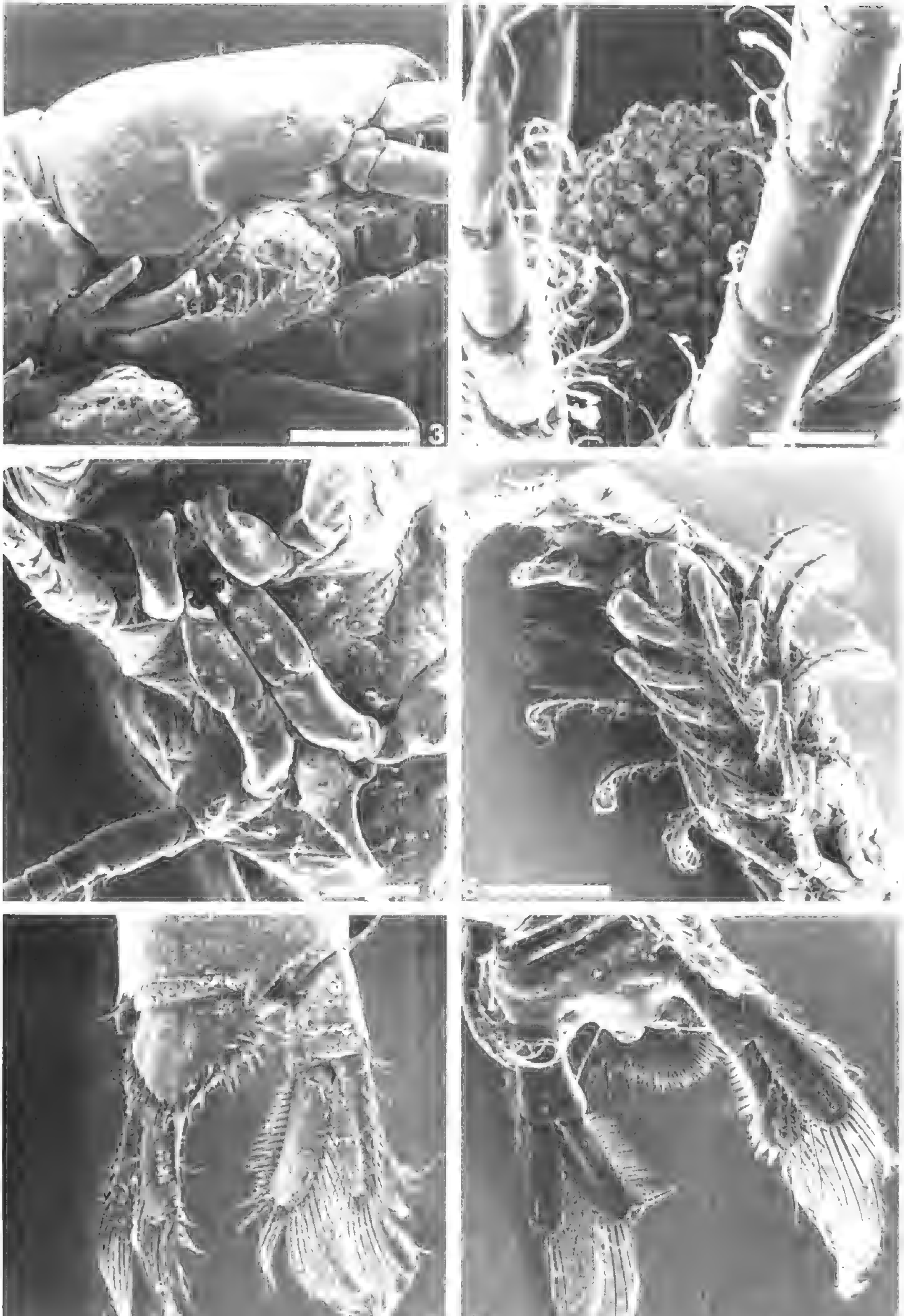
Acknowledgments

I thank Prof. W. D. Williams, Department of Zoology, University of Adelaide, for encouragement. Dr K. F. Walker brought my attention to the article by Morrison. Dr K. Bartusek, P. Kempster and J. Wright (University of Adelaide) are thanked for help with the SEM photography.



Figs 1-2. *Koonunga cursor* from locality (1). 1, undissected ♀; 2, undissected ♂. Both at same magnification. Scale: 500μ. Specimens frozen dried and coated with gold palladium before SEM photography.

Figs 3-8. *Koonunga cursor* from locality (1). 3, detail of fig. 1 to show cephalon with transverse sulcus; 4, detail of fig. 2 to show globular organ on ♂ antennule; 5, detail of fig. 2 to show ♂ copulatory appendages in ventral position; 6, detail of fig. 2 to show anterior appendages and globular organs on antennules; 7, ♀ telson viewed posterolaterally; 8, ♂ telson viewed ventrally.
Scale: 500μ for figs 3, 6, 7, 8; 50μ for fig. 4; 200μ for fig. 5.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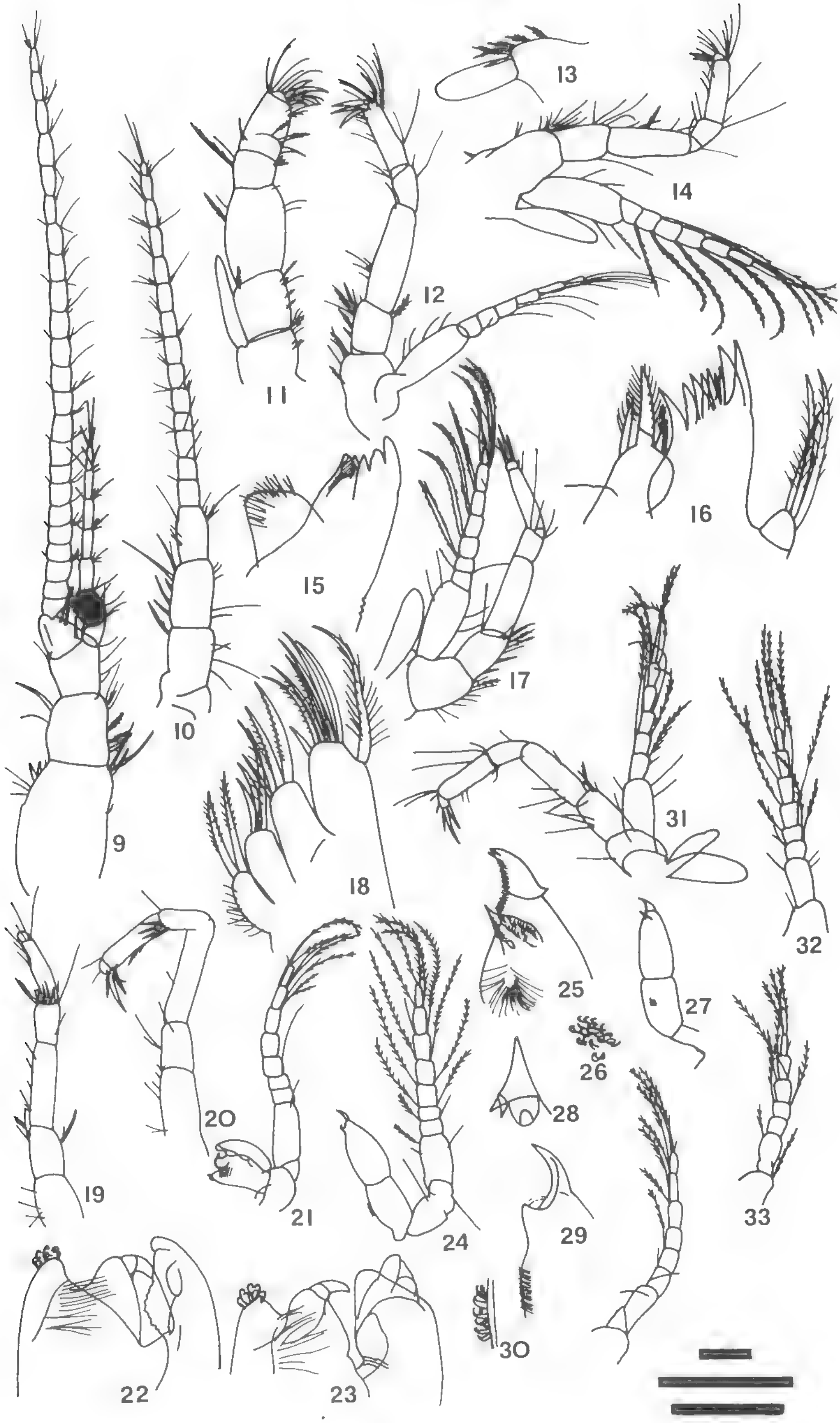
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Figs 9-34. *Koonunga cursor* ♂ left appendages except for figs 24, 29. 9, antennule; 10, antenna; 11, maxilliped; 12, first peraeopod; 13, endopodite plate of peraeopod; 14, second peraeopod; 15, mandibular coxale; 16, first maxilla; 17, third peraeopod; 18, second maxilla; 19, third peraeopod (claws missing); 20, fourth peraeopod; 21, first pleopod with endopodite; 22, detail of tip of endopodite; 23, detail of tip of endopodite, different orientation; 24, right second pleopod with endopodite; 25, detail of fig. 27—tip of endopodite of left second pleopod; 26, detail of fig. 27—coupling spines; 27, left second pleopod; 28, median appendage attached to sternum; 29, detail of fig. 24—tip of endopodite of right second pleopod; 30, detail of fig. 29—coupling spines; 31, fifth peraeopod; 32, penultimate pleopod; 33, last pleopod; 34, third pleopod.
Note: not all peraeopod endopodites are illustrated. Top scale: 500μ for figs 9-21, 31-34; middle scale: 500μ for figs 25, 28, 29; bottom scale: 100μ for figs 22, 23, 26, 30.

NEW UNIONICOLIDAE (ACARI, HYDRACHNELLAE) FROM AUSTRALIA

BY KURT O. VIETS

Summary

Seven new species of the water mite genus Unioncola, subgenus Pentatax (Acari, Hydrachnellae), are described from Australian freshwater mussels: Unioncola (Pentatax) walkeri n.sp., U. (P.) procursa n.sp., U. (P.) assimilis n.sp., U. (P.) conjunctella n.sp., U. (P.) ligulifera n.sp., U. (P.) clipeata n.sp., and U. (P.) scutata n. sp. A further new species is placed in Unionicolopsis opimipalpis n.g., n.sp.

NEW UNIONICOLIDAE (ACARI, HYDRACHNELLAE) FROM AUSTRALIA

by KURT O. VIETS*

Summary

VIETS, K. O. (1980) New Unionicolidae (Acari, Hydrachnellae) from Australia. *Trans. R. Soc. S. Aust.* **104**(2), 27-40, 29 February, 1980.

Seven new species of the water mite genus *Unionicola*, subgenus *Pentatax* (Acari, Hydrachnellae), are described from Australian freshwater mussels: *Unionicola* (*Pentatax*) *walkeri* n.sp., *U.* (*P.*) *procursa* n.sp., *U.* (*P.*) *assimilis* n.sp., *U.* (*P.*) *conjunctella* n.sp., *U.* (*P.*) *ligulifera* n.sp., *U.* (*P.*) *clipeata* n.sp. and *U.* (*P.*) *scutata* n.sp. A further new species is placed in *Unionicolopsis opimipalpis* n.g., n.sp.

Introduction

The Hydrachnellae are prostigmate Acari. Within the family Unionicolidae Oudemans, 1909 there are five subfamilies: Encentridophorinae Viets, 1935 (20 spp. from Africa, Australia, southern Asia), Najadicolinae Viets, 1935 (one sp., North America), Pionatacinae Viets, 1916 (many spp., world-wide), Pollicipalpinae Viets, 1914 (two spp., Africa) and Unionicolinae Oudemans, 1909. The Unionicolinae include four genera: *Unionicola* Haldeman, 1842 (many spp., world-wide), *Vietsatax* Uchida & Imamura, 1938 (one sp., Japan), *Heteratax* Lundblad, 1941 (one sp., Africa) and *Atacella* Lundblad, 1937 (six spp., South America).

The taxonomy of *Unionicola* and its associated subgenera still is somewhat unsatisfactory, but is based on the numbers of genital acetabulae, the appearance of the genital field, and the sexual differentiation of the legs of males. The diagnoses of systematic groups above subgenera were last summarized by Cook (1974). Species of the subgenus *Unionicola* s.s. possess six pairs of genital acetabulae; two species are known from Australia. Species of the subgenus *Pentatax* Thor, 1922 have five pairs of acetabulae; three Australian species are known.

Some species of *Unionicola* are free-living, others parasitic for part or all of their life cycle (e.g. in molluscs; Viets & Plate 1954; Mitchell 1955; Hevers 1978a, 1978b). The life histories of most species, however, are unknown. In Australia, one *Unionicola* species only has been reported in association with a freshwater mussel, namely *U.* (*U.*) *cirrosa* Koenike 1914, in the mussel *Unio nepeanensis* (syn. *Hyridella australis* (Lamarck)). Although the precise locality in Australia is unknown, the host mussel is likely to have come from a coastal stream in the southeast of the continent (cf. McMichael & Hiscock 1958).

Recently I obtained collections of water mites from various Australian freshwater mussels (Hyriidae) through Dr K. F. Walker of the University of Adelaide; I am grateful to him and the other collectors. Dr Walker also adapted this manuscript from the original German. From the material seven new species of *Unionicola*, subgenus *Pentatax* are described, and *Unionicolopsis* n.g., is erected for an additional new species.

General Remarks

The types and paratypes described herein are catalogued in the Viets Collection (Wilhelmshaven), and ultimately will go to the Senckenberg-Museum, Frankfurt.

The legs of water mites are 6-segmented: 1 trochanter, 2 basifemur, 3 telofemur, 4 genu, 5 tibia, 6 tarsus. The legs and their segments usually are symbolized as, for example, first leg tarsus: I.L.6 and fourth leg tibia: IV.L.5 (see Cook 1974: Fig. 5). The palps are 5-segmented: 1 trochanter, 2 femur, 3 genu, 4 tibia, 5 tarsus. These are denoted P I–V (Cook 1974: Fig. 6).

All measurements herein are μm.

Unionicola (Pentatax) walkeri n.sp.

FIGS 1–8

Holotype ♀ prep. 6638: With soft integument. In dorsal integument lie two pairs of delicate, oblong plates (muscle attachment sites), anterior pair nearer one another than the posterior pair; length 38–50.

Coxal area (Fig. 2) 415 long. Third coxae considerably shorter in mid-line than fourth coxae; suture between coxal pairs does not

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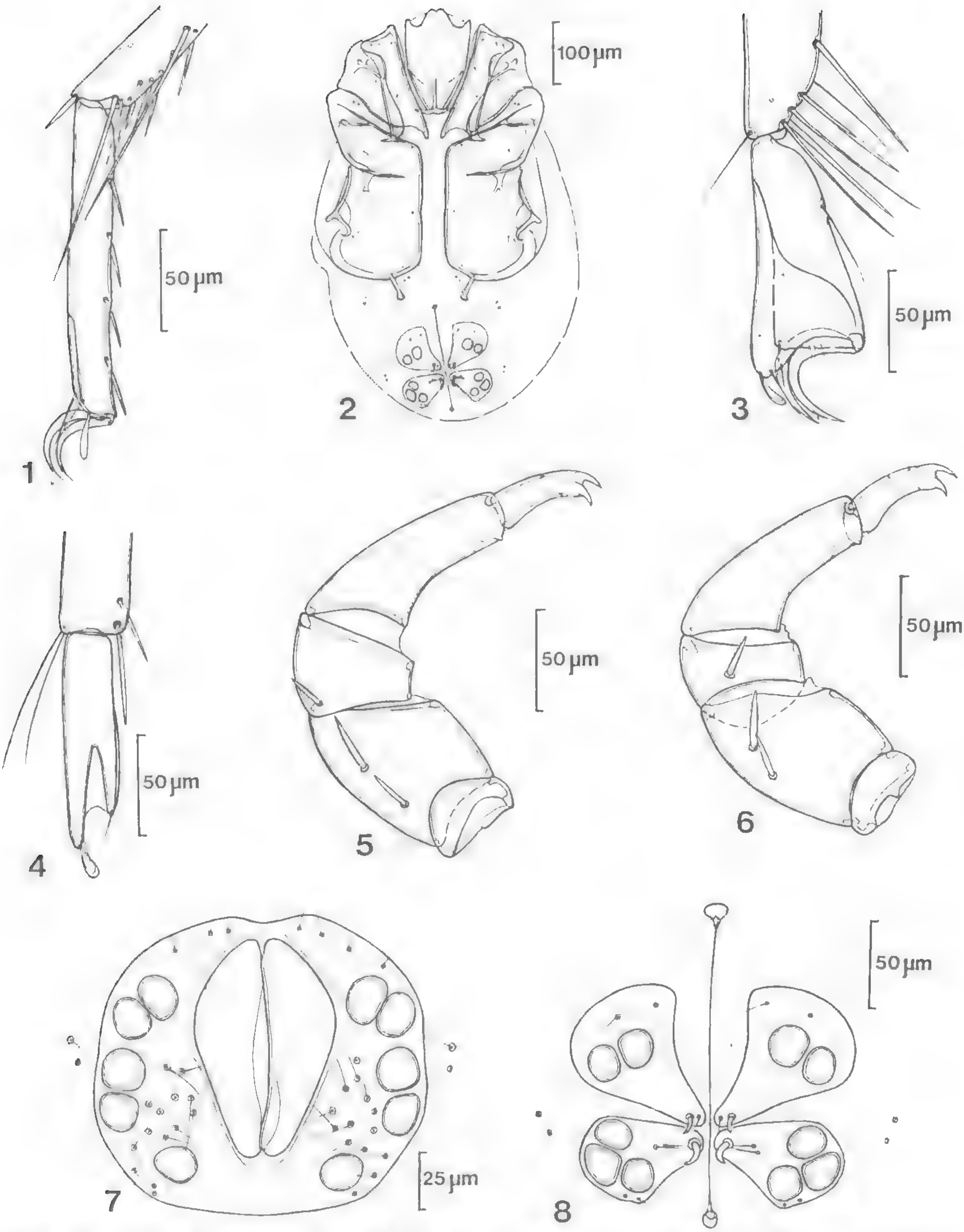


Figs 1–8. *Unionicola* (*Pentatax*) *walkeri* n.sp. 1. ♀ holotype prep. 6638, IV.L.5–6, right; 2. ♀ holotype, ventral side; 3. ♀ holotype, I.L.5–6, left; 4. ♂ prep. 6675, I.L.5–6, right, dorsal aspect; 5. ♀ holotype 6638, right palp; 6. ♂ allotype prep. 6642, left palp; 7. ♂ allotype prep. 6642, genital field; 8. ♀ holotype prep. 6638, genital field.

reach medial margin. Posterior margins of fourth coxae rounded, and each with posteriorly-directed process. Medial margin of third and fourth coxae 198 long.

Genital field (Fig. 8) entirely at posterior end of body. It consists of two pairs of medially-constricted plates; anterior pair each with two genital acetabulae, and posterior pair each with three acetabulae. On strongly-tapered medial edge of each anterior plate short, stout seta ("stylet"), and near it smaller, slender seta. On medial edge of each posterior plate large, thick, curved seta, and alongside two (in some cases three) slender setae. Gonopore (about 182 long) surrounded by pre- and post-genital sclerites.

Capitulum (Fig. 2) 162 long, c. 104 wide. Chelicerae similar to those of other *Unionicola* species. Dorsal palp segment lengths (left P I–V): 10 , 105 , 53 , 109 , 54. P II on each side with two setae, and P III one seta. P IV has no ventral process, apart from a minute, often indistinct, peg-like seta at its distal end. P V ends in two strong claws.

Legs I–IV with number of ventrally-attached setae. On segment 5 of all legs, and on segment 4 of legs III and IV, are 3 long, slender swimming-setae (cf. Cook 1974: Fig. 5), located distally. Last segment of leg I (Figs 3–4), seen from side, strongly expanded distally (i.e. dorso-ventrally expanded) to form large claw fossa. On dorsal side, at distal end of segment, slender-based, spoon-shaped, chitinous structure. In Fig. 4 tarsal claws omitted. Club-shaped structure situated on distal end of IV.L.6 (Fig. 1). Small, spoon-shaped seta attached near tarsal claws on II.L.6 and III.L.6. Tarsal claws simple in form, having no carpus, but with slender, terminal spine. Dorsal segment lengths of legs I and IV: I.L.3–6: 74 , 115 , 97 , 118; IV.L.3–6: 94 , 155 , 180 , 165.

Allotype ♂ prep. 6642: Coxal area (length 410) and dorsal side correspond closely with ♀. Genital field located terminally as an enclosed plate 127 long and 145 wide. For arrangement of genital acetabulae and hair-pores, see Fig. 7.

Capitulum 149 long and c. 100 wide. Palps (Fig. 6) similar to ♀, left P I–V, measured dorsally, as follows: 11 , 97 , 54 , 105 , 53. Legs similar to ♀; dorsal segment-lengths: I.L.3–6: 70 , 111 , 99 , 114: IV.L.3–6: 92 , 146 , 170 , 152.

Variation: coxal area, length 415–453 ♀♀(7), 350–433 ♂♂(9); gonopore, length incl. sclerites 169–188, , genital field ♂, length , 114–127: genital field ♂, width ..., 124–165; capitulum, length 162–177, 143–159; capitulum, width 103–114, 91–101; chelicera, length (152), (135–152); palp, dorsal segment length P I 8–13, 7–11, P II 99–113, 82–105; P III 46–62, 47–59; P IV 109–120, 100–114; P V 53–58, 44–57; legs, segment length I.L.3 74–84, 69–76; I.L.4 114–124, 103–119; I.L.5 95–107, 89–105; I.L.6 110–122, 104–121; IV.L.3 94–104, 83–99; IV.L.4 155–170, 135–158; IV.L.5 177–198, 157–182; IV.L.6 165–175, 146–159; egg, long axis 135–143.

Hosts and localities (all S. Aust.): *Alathyria jacksoni* Iredale, Lock 3, River Murray, K. F. Walker, 19.xi.1977 (1 ♂, 1 ♀, holotype); Lock 3, R. Murray, K. F. Walker, 5.xi.1977 (1 ♂, allotype); *Velesunio ambiguus* (Phillipi), Lock 3, R. Murray, K. F. Walker, 19.xi.1977 (8 ♂, 7 ♀); Point Sturt, Lake Alexandrina (R. Murray) K. F. Walker, 30.x.1977 (4 ♀); L. Alexandrina nr Milang, M. C. Geddes, 20.xi.1977 (3 ♂, 2 ♀); Point Sturt, L. Alexandrina K. F. Walker, 3.xii.1977 (3♂, 2 ♀).

Unionicola (Pentatax) procursa n.sp.

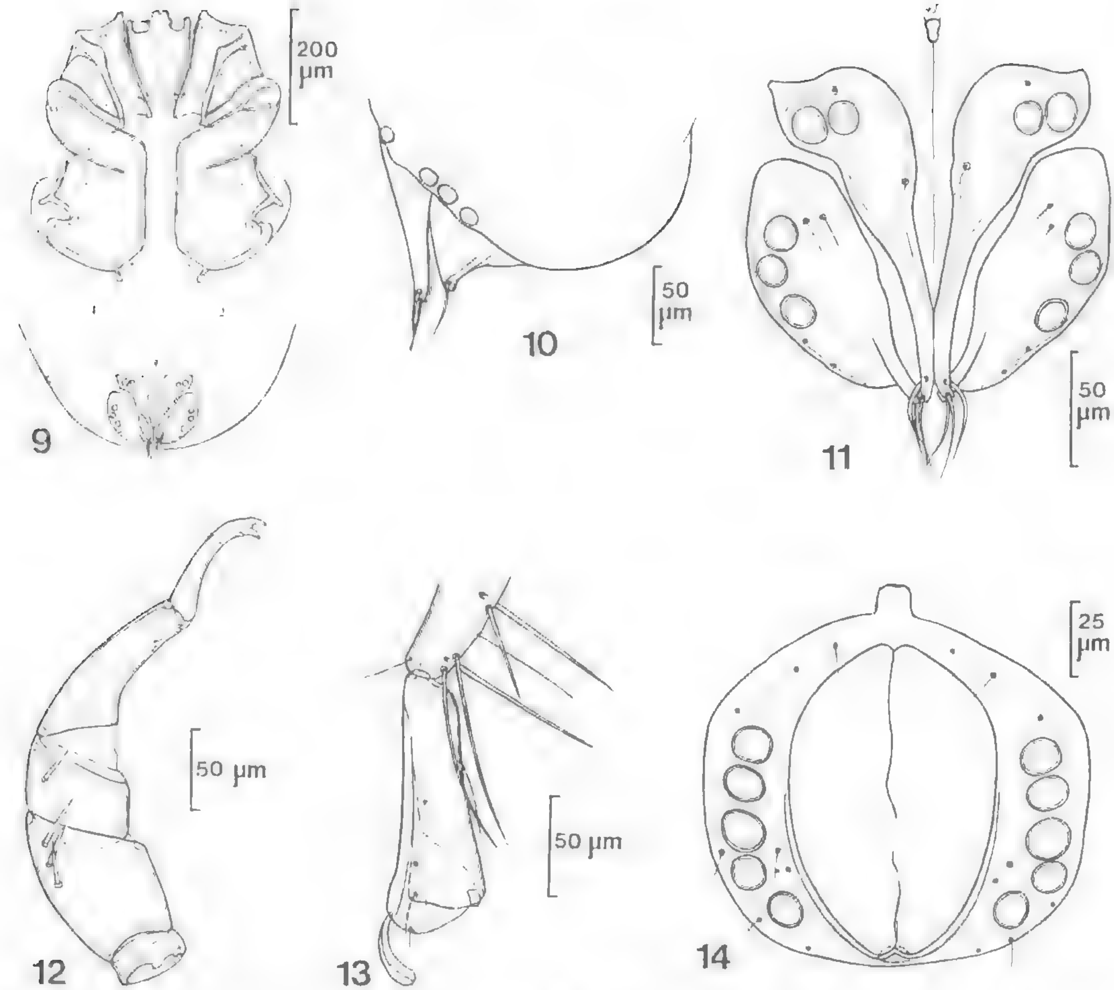
FIGS 9–14

Holotype ♀ prep. 6671: Dorsal integument and coxal area (Fig. 9) very similar to *U.* (*P.*) *walkeri* n.sp., although posterior process of fourth coxa somewhat shorter. Coxal area 446 long.

Genital field (Fig. 10, lat. view) at end of body. In dorsal aspect (Fig. 11) abdominal integument at anterior margin of field indented (although this is not clear from Fig. 10). Anterior plates of genital field, each with two acetabulae, directed posteriorly. Each anterior plate with two stout setae at hindmost extremity. Posterior plates broader, and bear one seta at the ends of their respective posterior processes.

Capitulum 150 long and 104 wide anteriorly. Chelicerae like those of congeners. Long, slender P V (Fig. 12), and, as with related species, two distinct terminal claws. P III with two setae on outer border, and three inner setae. Dorsal segment lengths (left P I–V): 15 , 110 , 60 , 116 , 73.

I.L.6 similar to that of *U.* (*P.*) *walkeri* n.sp. (Fig. 13; tarsal claws omitted for clarity). It is, however, smaller and the distal border of the expanded part of the large claw fossa is convexly rounded, not strongly indented as in other species. Large, spoon-shaped appendage



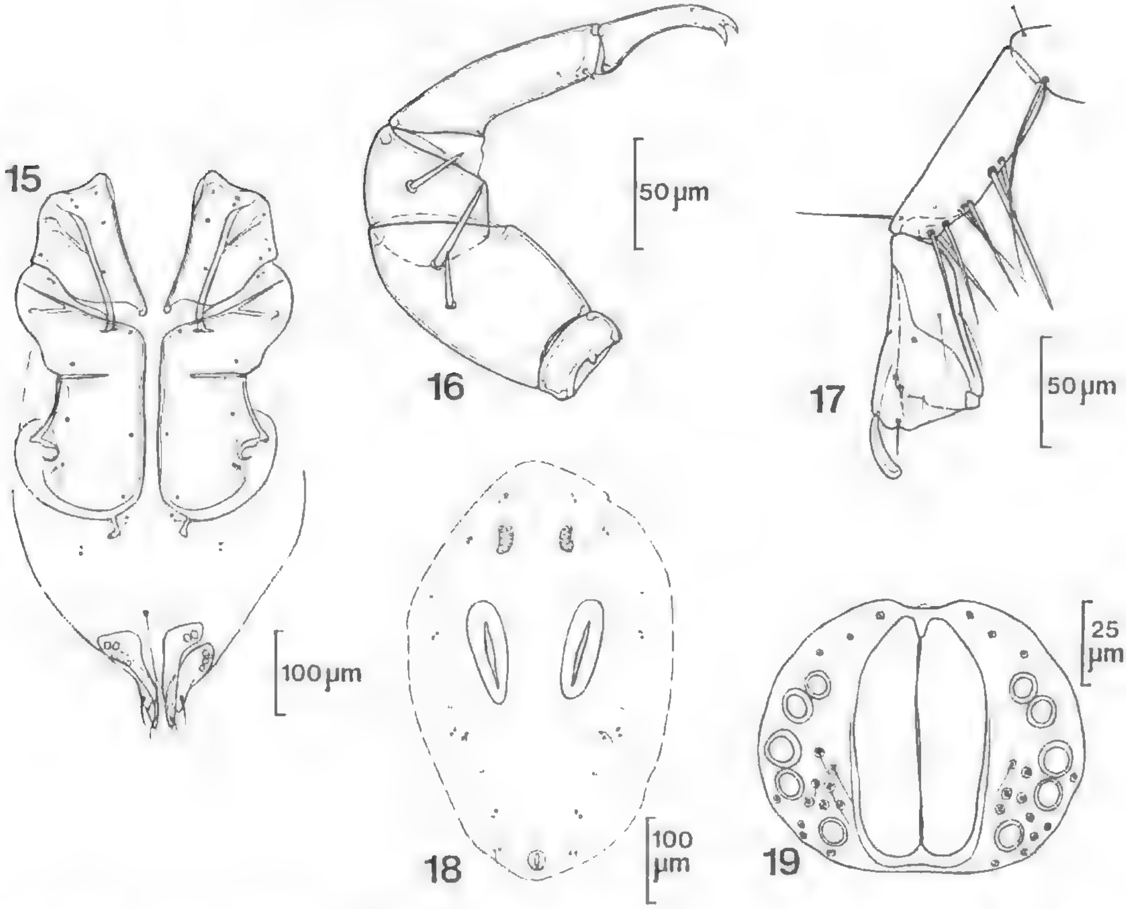
Figs 9–14. *Unionicola (Pentatax) procursa* n. sp. 9. ♀ holotype, prep. 6671, ventral side; 10. ♀ paratype, prep. 6673, genital field, lateral view; 11. ♀ holotype, genital field; 12. ♀ holotype, left palp; 13. ♀ holotype, I.L.5–6, left; 14. ♂ allotype, prep. 6676, genital field.

on I.L.6 like that of *U.* (*P.*) *walkeri* n.sp. Stout seta on dorsal side of II and III.L.6, proximal to each claw; tends to a spoon-shape on leg II, but simple on leg III. No club-shaped chitinous structure on end of IV.L.6, as in related species. Otherwise leg setation shows no significant differences. Dorsal segment lengths: I.L.3–6: 95 . 163 . 117 . 129; IV.L.3–6: 104 . 168 . 183 . 167.

Allotype ♂ prep. 6676: ♂ and ♀ very similar. Coxal area 365 long. Genital field (Fig. 14) differs from other species in form and especially number of hair-pores. A small anterior projection, 114 and 126 wide dorsally.

Capitulum dimensions 122 : 85. Chelicerae 126 in length. Palps as in ♀; dorsal segment lengths (left P I–V): 14 . 94 . 50 . 100 . 64. Legs as in ♀. Dorsal segment lengths: I.L.3–6: 78 . 124 . 92 . 109; IV.L.3–6: 82 . 130 . 139 . 144.

Variation: coxal area, length 365–393 ♂♂ (4), 405–446 ♀♀ (5); capitulum, length 122-133, 135–150; capitulum, width 83–90, 94–104; palp, dorsal segment length P I 12–14, 13–16; P II 90–100, 98–110; P III 44–51, 51–64; P IV 101–105, 112–119; P V 59–67, 64–73; genital field (♂), length 114–120, ; genital field (♂), width 126–137, ; legs, segment length I.L.3 75–80, 88–97; I.L.4 121–128, 144–164; I.L.5 92–99, 105–117; I.L.6 105–109, 115–129; IV.L.3 79–85, 92–108; IV.L.4 129–139, 149–169; IV.L.5 139–151, 164–183;



Figs 15–19. *Unionicola* (*Pentatax*) *assimilis* n.sp. 15. ♀ holotype, prep. 6625, ventral side; 16. ♀ holotype, left palp; 17. ♀ holotype, I.L.5–6, left; 18. ♂ paratype, prep. 6635, dorsum; 19. ♂ allotype, prep. 6633, genital field.

IV.L.6 137–146, 161–168; egg, long axis , 160–163.

Host and localities (all S. Aust.): *Velesunio ambiguus*, R. Murray nr Mannum, K. F. Walker, 19.xi.1977 (1 ♂); Point Sturt, L. Alexandrina (R. Murray), K. F. Walker, 30.x.1977, (5 ♂); L. Alexandrina nr Milang, M. C. Geddes, 20.xi.1977 (7♂, 1 ♀, incl. holotype and allotype); Point Sturt, L. Alexandrina (R. Murray), K. F. Walker, 3.xii.1977 (5 ♀).

Unionicola (Pentatax) assimilis n.sp.

FIGS 15–19

Holotype ♀ prep. 6625: Ridged posterior plates of dorsal integument (Fig. 18, ♂) about 130 long. Coxal area (Fig. 15) length 406. As in the other species, suture between the third and fourth coxae does not reach medial margin, and is directed transversely. Genital field, capitulum and chelicerae similar to *U.* (*P.*) *procursa* n.sp. P II (Fig. 16) bears two setae on inner and outer sides. P V ends in two claws; length in same proportion to P IV as in other species. Dorsal lengths of P II and P IV nearly identical, whereas in *U.* (*P.*) *procursa* n.sp. P IV is slightly longer than P II. Dorsal segment lengths (left P I–V): 11 . 105 . 50 . 103 . 61.

I.L.6 (Fig. 17) expanded distally, and 52.6–62.7% of segment length; it is also shorter in proportion to I.L.5 (90.5–101.2%) than is the case for *U.* (*P.*) *procursa* n.sp. (106.5–118.5%). I.L.6 bears a spoon-shaped distal projection like the other species. On II.L.6 and III.L.6, however, only one stout seta at distal end of dorsal edge, and this is not spoon-shaped. Dorsal segment lengths: I.L.3–6: 84 . 136 . 95 . 90; IV.L.3–6: 90 . 144 . 172 . 149.

Allotype ♂ prep. 6633: Dorsal integument, coxal area, palps and legs similar to ♀. Posterior dorsal plates about 115 long, with strong chitinous ridge (Fig. 18). Coxal area length 355. Genital field (Fig. 19) about 80 long and 97 wide, weakly indented at anterior border.

Capitulum dimensions 132 : 79. Dorsal palp segment lengths (left P I–V): — . — . 42 . 85 . 54. Dorsal leg segment lengths: I.L.3–6: 74 . 110 . 85 . 81; IV.L.3–6: 75 . 123 . 150 . 134.

Variation: coxal area, length 344–380 ♂♂ (6), 400–442 ♀♀ (6); posterior dorsal plate, length 105–137, 125–140; capitulum, length 124–138, 143–157; capitulum, width 76–85, 94–100; chelicerae, length (102), (125–132); palp, dorsal segment length P I 10–12, 10–13; P II 85–97, 102–112; P III 42–48, 50–62; P IV 82–89, 99–110; P V 50–54, 56–67; genital field (♂), length (77–85), ; genital field (♂), width 89–108, ; leg, segment length I.L.3 65–83, 84–98; I.L.4 104–119, 136–145; I.L.5 77–89, 95–105; I.L.6 75–85, 89–97; IV.L.3 71–84, 89–97; IV.L.4 115–132, 144–155; IV.L.5 142–160, 172–186; IV.L.6 130–139, 147–165; egg, long axis , (133–138);

Host and locality: Westralunio carteri Iredale, Murray River S of Dwellingup, W. Aust., N. M. Morrissy, 15.xii.1977 (8♂, 13 ♀, 11 nymphs, incl holotype and allotype).

Remarks: Allied to *U.* (*P.*) *procursa* n.sp. Significant differences between the two species are summarized in Table 1.

Unionicola (Pentatax) conjunctella n.sp.

FIGS 20–25

Holotype ♀ prep. 6669: Dorsal side (Fig. 23, ♂) like that of *U.* (*P.*) *assimilis* n.sp. Ridged plates (c. 135 long) very thin, outline not always evident, in contrast to ridge itself. Coxal area (Fig. 20) 360 long. Suture between third and fourth coxae runs obliquely, approximately parallel to anterior margin of third coxae, and fused with medial edge of posterior plates. Genital field (see Fig. 20) similar to other species.

Capitulum 142 long and 87 wide, and, like the chelicerae, with no distinctive characteristics. Palp (Fig. 21) segment P II bears two setae on each of its inner and outer sides. Dorsal lengths of segments (left P I–V): 12 . 89 . 42 . 91 . —.

I.L.6 (Fig. 22) similar to that of *U.* (*P.*) *assimilis* n.sp. Terminal segments of legs II and III each with expanded spoon-shaped seta dorsally, at distal end, in front of tarsal claws. Dorsal segment lengths: I.L.3–6: 64 . 93 . 72 . 76; IV.L.3–6: 77 . 115 . 140 . 125.

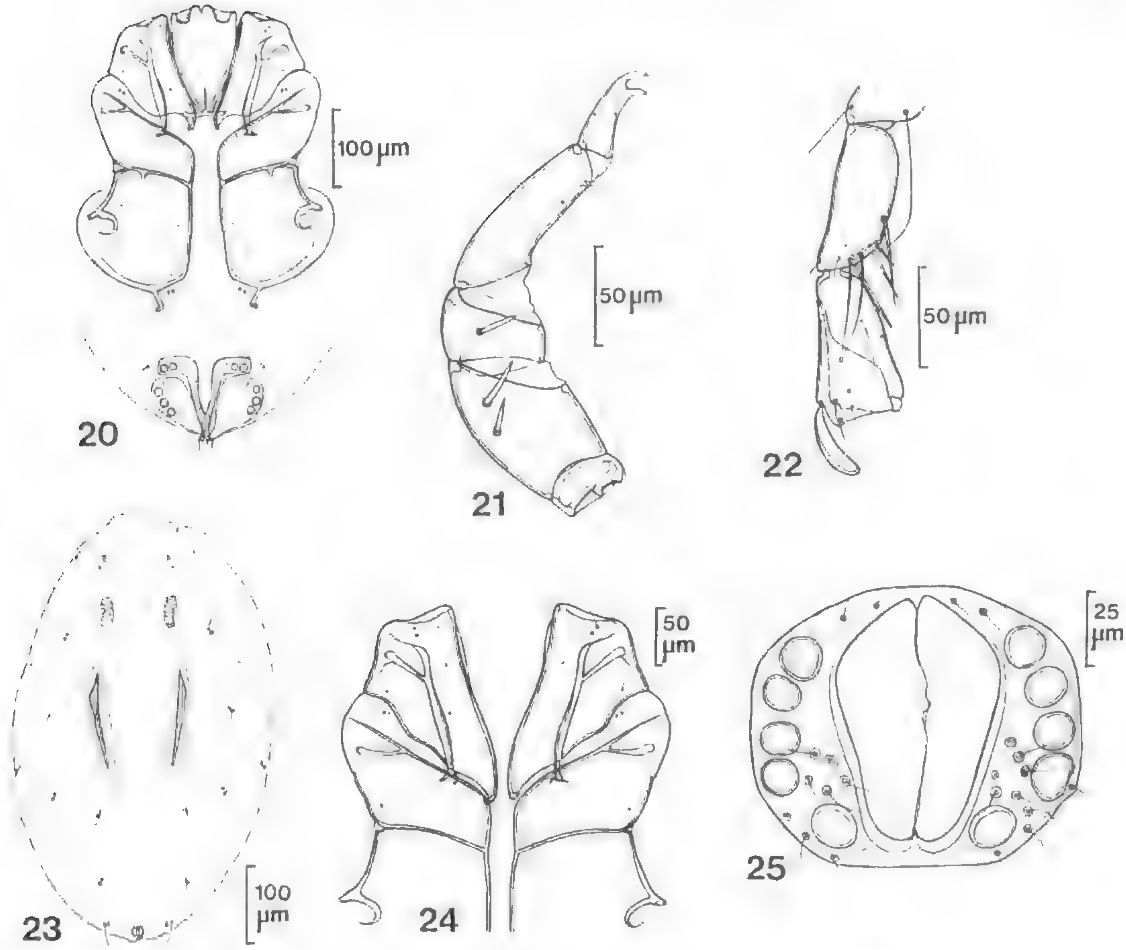
Allotype ♂ prep. 6663: Dorsal side (Fig. 23) similar to ♀. Length of posterior plates 158. Coxal area 386 long. Unlike ♀, first coxae (Fig. 24) extend posteriorly beyond ends of outer apodemes. Genital field 94 long and 110 wide. (Fig. 25) like *U.* (*P.*) *assimilis* n.sp.

Capitulum 140 long and 87 wide. Palps similar to ♀; dorsal segment lengths (left P I–V): 10 . 93 . 45 . 93 . 47. Legs also similar to ♀. Dorsal segment lengths: I.L. 3–6: 66 . 99 . 76 . 80; IV.L.3–6: 77 . 119 . 147 . 132.

Variation: coxal area, length 340–406 ♂♂ (7), 320–380 ♀♀ (4); posterior dorsal plates, length 130–158, 130–135; capitulum, length 125–145, 124–142; capitulum, width 76–90, 80–87; chelicera, length (110–125), (115); palp, dorsal segment length P I 10–13, (12); P II 79–97, 83–89; P III 37–47, 40–45; P IV 84–98, 84–93; P V 43–48, 42–47; genital field (♂), length (81–94), ; genital field (♂), width 107–129, ...; legs, segments length I.L.3 57–71, 58–64; I.L.4 85–105, 85–94; I.L.5

TABLE 1. *Comparison of* U. (P.) assimilis *and* U. (P.) procursa

	U. (*P.*) *assimilis n.sp.*	*U.* (*P.*) *procursa* n.sp.
dorsal integument	1 pair small ant. muscle attachment sites; 1 pair post. plates with strong ridge	1 pair small ant. muscle attachment sites; 1 pair post. plates without strong ridge
suture between coxae 3 and 4	transverse	oblique, ± parallel to ant. border of 3rd coxa
genital field (♂)	without medial process; post. ½ with many hair-pores	with medial process; post. ½ with few hair-pores
P II inner side	2 setae	3 setae
I.L.6	± broad	± slender
max. width as % segment length	♂♂: 54.3–63.7% ♀♀: 52.6–60.0%	♂♂: 40.2–41.3% ♀♀: 36.8–40.0%



Figs 20–25. *Unionicola* (*Pentatax*) *conjunctella* n.sp. 20. ♀ holotype, prep. 6669, ventral side; 21. ♀ holotype, left palp; 22. ♀ holotype, I.L.5–6; 23. ♂ allotype, prep. 6663. dorsum; 24. ♂ paratype, prep. 6662, coxal area; 25. ♂ allotype, genital field.

66–83, 66–76; I.L.6 71–88, 72–77; IV.L.3 69–87, 70–77; IV.L.4 105–129, 108–121; IV.L.5 131–155, 136–148; IV.L.6 120–143, 117–131; I.L.6, maximum width 43–50, 44–47; egg, long axis .., (165).

Hosts and localities: Alathyria jacksoni, Lock 3, R. Murray, S. Aust., K. F. Walker, 19.xi.1977 (1 ♂); *Velesunio ambiguus*, R. Murray nr Mannum, S. Aust., K. F. Walker, 19.xi.1977 (2 ♂, 1 ♀); Lock 3, R. Murray S. Aust., K. F. Walker, 19.ix.1977 (3♂, incl. allotype, 1 ♀); Rocklands Reservoir, Vict., P. J. Suter, 20.xi.1977 (1 ♂); Point Sturt, L. Alexandrina (R. Murray), S. Aust., K. F. Walker, 30.x.1977 (1 ♂ holotype).

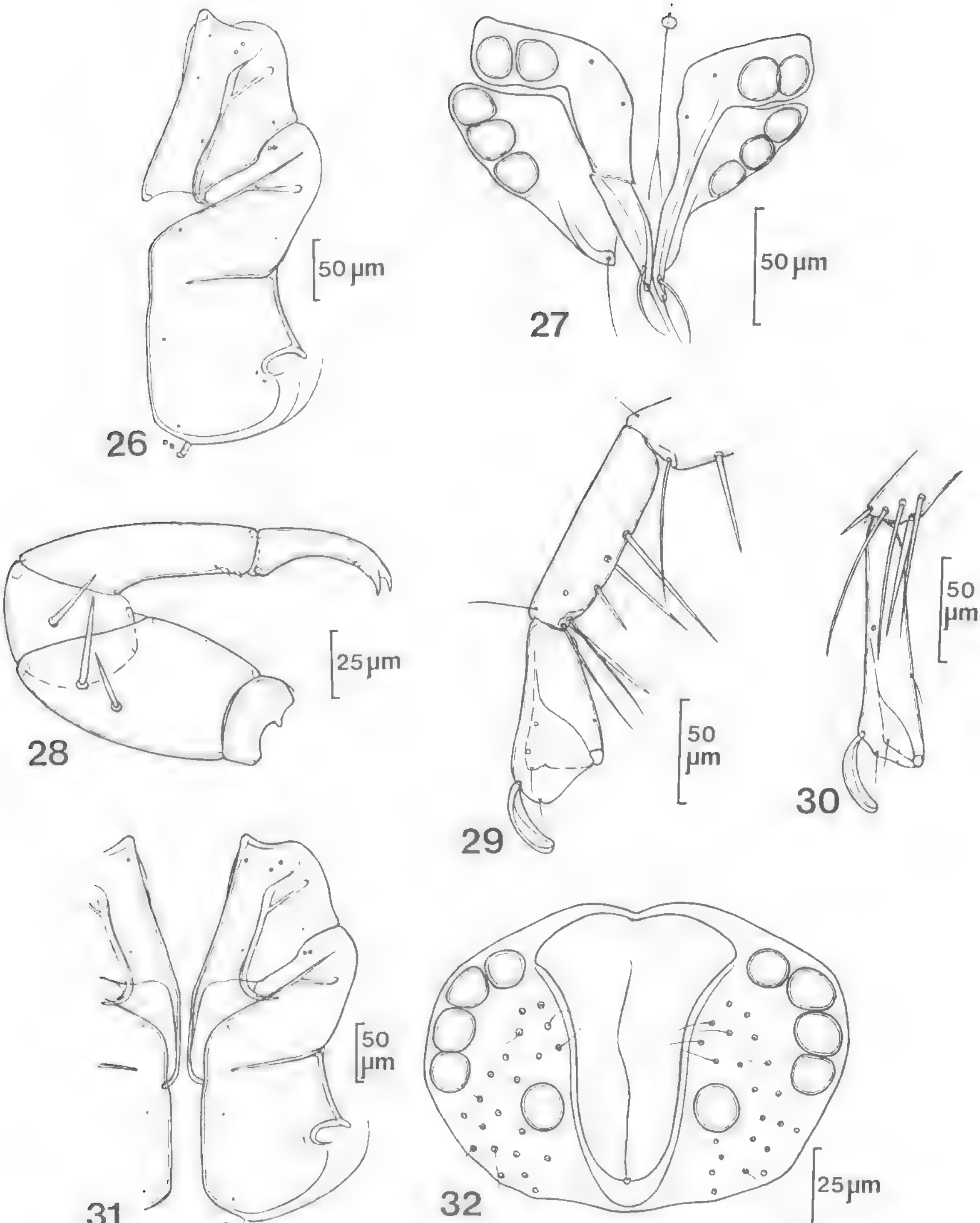
Remarks: Distinguished from *U.* (*P.*) *procursa* n.sp. and *U.* (*P.*) *assimilis* n.sp. in that suture between third and fourth coxae extends to medial margin of posterior plates.

P V is considerably shorter than in other species, as seen in comparisons of P V length as % P IV length (♂ + ♀): *U.* (*P.*) *conjunctella* n.sp. 46.2–53.6%; *U.* (*P.*) *procursa* n.sp. 57.1–65.7%; *U.* (*P.*) *assimilis* n.sp. 56.0–64.3%.

Unionicola (Pentatax) ligulifera n.sp

FIGS 26–32

Holotype ♀ prep. 6664: As with *U.* (*P.*) *conjunctella* n.sp., dorsally two separate, thin plates with prominent chitinous ridges. Coxal area (Fig. 26) 373 long. First coxae do not extend beyond posterior ends of apodemes. Suture between third and fourth coxae short and does not reach medial margin. Genital field (Fig. 27) like that of other species except *U.* (*P.*) *walkeri* n.sp.



Figs 26–32. *Unionicola (Pentatax) ligulifera* n.sp. 26. ♀ holotype, prep. 6664, coxal area, left; 27. ♀ holotype, genital field; 28. ♀ holotype, left palp; 29. ♀ holotype, I.L.5–6, left; 30. ♀ holotype, III.L.5–6, left; 31. ♂ allotype, prep. 6666, coxal area; 32. ♂ allotype, genital field.

Capitulum dimensions 120 : 81. P II (Fig. 28) bears two setae on inner and outer sides. P V long, 57-58% of P IV length. Dorsal segment length (left P I–V): 12 . 85 . 44 . 91 . 52.

I.L.6 (Fig. 29) shorter than I.L.5 and typical of other species in the *Pentatax* group. II and III.L.6 (Fig. 30), like I.L.6, each with a large spoon-shaped chitinous structure distally. Species in related groups have, on these segments, minute setae only slightly expanded distally. Dorsal segment lengths: I.L.3–6: 72 . 118 . 100 . 89; IV.L.3–6: 85 . 133 . 152 . 139.

Allotype ♂ prep. 6666 (+ *paratype* ♂, *in toto*): Dorsal integument similar to ♀. Coxal area (Fig. 31) 332(326) long (paratype dimensions in parentheses). First coxae slender in mid-posterior region and wide and elongate at extremity. Genital field (Fig. 32) 134 wide. Foremost four acetabulae on either side arranged in rows.

Capitulum 103(102) long and 70(69) wide. Palps as in ♀; dorsal segment lengths (left P I–V): 10(12) . 71(71) . 34(37) . 77(77) . 45(45). Legs similar to ♀. Dorsal segment lengths: I.L.3–6: 59 . 97 . 87 . 78; IV.L.3–6: 73 . 116 . 132 . 117.

Hosts and localities: Alathyria jacksoni, Lock 3, R. Murray, S. Aust., K. F. Walker, 19.xi.1977 (1 ♂); *Velesunio ambiguus*, Lock 3, R. Murray, S. Aust., K. F. Walker, 19.xi.1977 (1 ♀, 2 ♂, incl. holotype and allotype).

Remarks: Distinctive in that II. and III.L.6 each bear, on their distal-dorsal margins, a large, spoon-shaped chitinous structure similar to that borne on I.L.6 Although in the ♀ the first coxae do not extend beyond the posterior apodemes, they are very long in the ♂, markedly longer than in the ♂ of *U.* (*P.*) *conjunctella* n.sp. The projection extends to the suture between the third and fourth coxae. The suture does not reach the medial margin of the posterior plates.

Unionicola (Pentatax) clipeata n.sp.

FIGS 33–38

Holotype ♀ prep. 6647 (*paratype* ♀ prep. 6649): (Measurements of paratype in parentheses). Weakly chitinized, undivided dorsal shield has dimensions: 202(188) 180(171). Coxal area (Fig. 33) 302(271) long. First coxae do not extend beyond posterior end of apodemes. Suture between third and fourth coxae curved over entire length, and meets medial margin of posterior plates. Fourth coxae have almost right-angled medial-posterior margin. Genital field (see Fig. 33) similar to preceding species.

Capitulum dimensions 112(95), 67(60), chelicerae 87 long. P II (Fig. 34) has two setae on inner and outer sides. Relative length of P V between that of *U.* (*P.*) *conjunctella* n.sp. and *U.* (*P.*) *procursa* n.sp. Dorsal segment lengths (left P I–V): 11(8) . 60(55) . 36(29) . 66(63) . 38(33).

I.L.6 (Fig. 35) relatively short and wide (61.3–67.2% of segment length), and with convex distal margin. Distal-dorsal setae on legs II and III only slightly expanded. Dorsal leg segment lengths: I.L.3–6: 51(48) . 70(68) . 53(52) . 61(59); IV.L.3–6: 59(55) . 89(86) . 107(106) . 94(96).

Allotype ♂ prep. 6648 (+ *paratype* ♂ prep. 6650): Dimensions of dorsal shield (Fig. 36) 208 : 178. Coxal area 288(280) long, similar to ♀. Genital field (Fig. 37) with many hair pores, indented anteriorly and 127(132) wide.

Capitulum 99 long and 63 wide. Palp dorsal segment lengths (left P I–V): —(8) . 58(59) . 32(30) . 62(61) . 36(33); Legs similar to ♀. Dorsal segment lengths: I.L.3–6: 50(51) . 69(70) . 53(54) . 62(61); IV.L.3–6: 56(58) . 82(86) . 105(103) . 95(96).

Host and locality: Velesunio ambiguus, R. Murray nr Mannum, S. Aust., K. F. Walker, 19.xi.1977 (2 ♂, 2 ♀, incl. holotype and allotype).

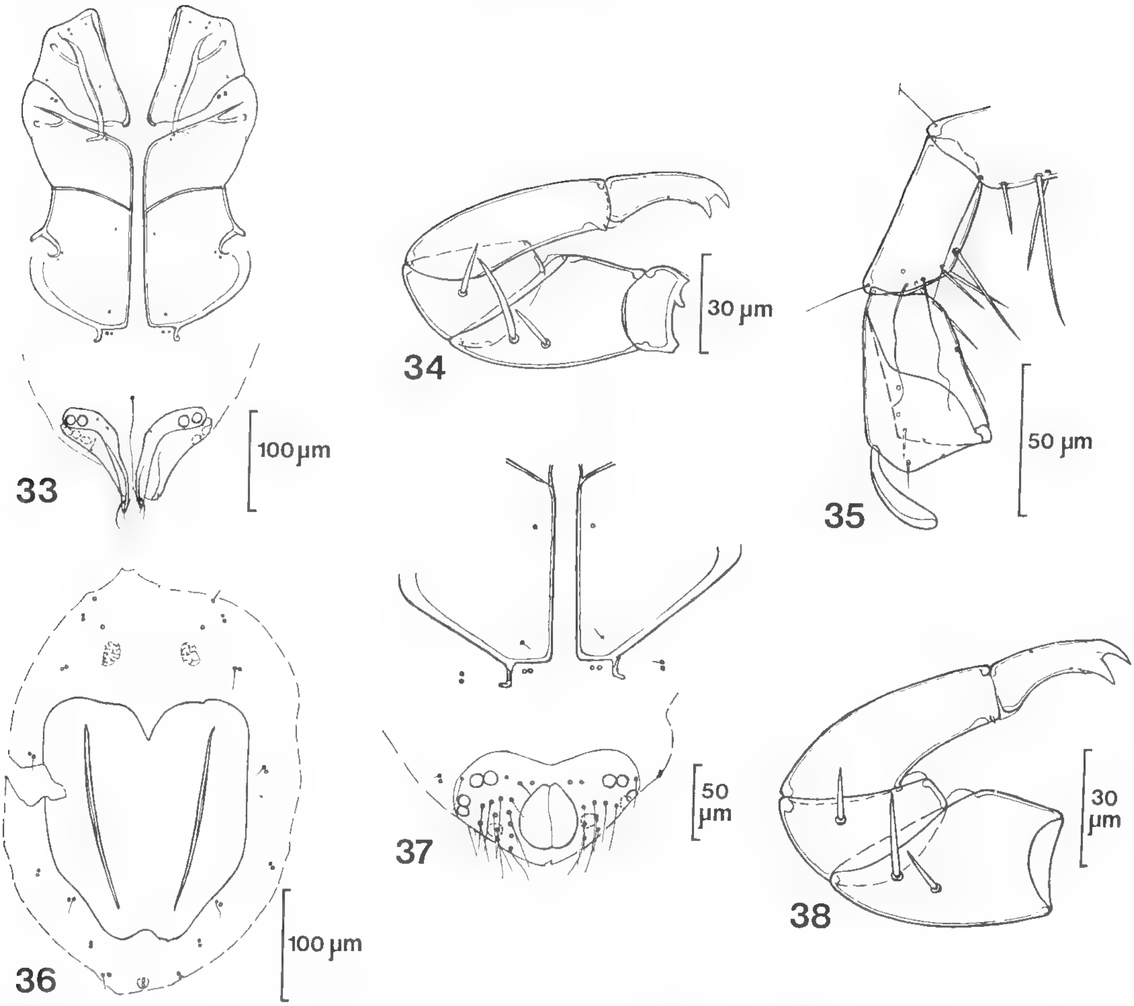
Unionicola (Pentatax) scutata n.sp.

FIGS 39–45

Holotype ♀ prep. 6679: Dorsal shield (Fig. 39) about 280 long and finely pored. On each side small, weakly chitinized shield, with hair-pore, in front of anterior muscle attachment sites. Coxal area (Fig. 40) 366 long. Suture between third and fourth coxae extends to medial margin of posterior plates. First coxa does not extend beyond end of posterior apodemes. Genital field (see Fig. 40) similar to other species.

Capitulum 114 long and 76 wide. P II (Fig. 41) with 2 setae on inner and outer sides. Dorsal segment lengths (left P I–V): 13 . 68 . 35 81 . 40.

I.L.6 (Fig. 42) similar to other species; as with *U.* (*P.*) *clipeata* n.sp., slightly longer than penultimate segment. Distal-dorsal setae on II. and III.L.6 only slightly broadened (cf. spoon-shaped). IV.L.6 (Fig. 43) has, in the middle of its distal extremity, club-shaped chitinous structure comparable to *U.* (*P.*) *walkeri* n.sp.



Figs 33–38. *Unionicola* (*Pentatax*) *clipeata* n.sp. 33. ♀ holotype, prep. 6647, ventral side; 34. ♀ holotype, left palp; 35. ♀ holotype, I.L.5–6, left; 36. ♂ allotype, prep. 6648, dorsum; 37. ♂ allotype, ventral side, posterior; 38. ♂ allotype, left palp.

Dorsal leg segment lengths: I.L.3–6: 55 . 88 . 65 . 64; IV.L.3–6: 66 . 110 . 138 . 123.

Allotype ♂ prep. 6680 (+ *paratype* ♂ prep. 6681): (Dimension of paratype given in parentheses). Dorsal side similar to ♀. Coxal area (Fig. 44) 333(375) long. First coxae extend beyond end of posterior apodemes (in these characters the ♂ is similar to the ♂ of *U.* (*P.*) *conjunctella* n.sp.). Genital field (see Fig. 44) 138(158) wide, and posterior margin (Fig. 45) indented; large numbers of hair-pores in posterior area.

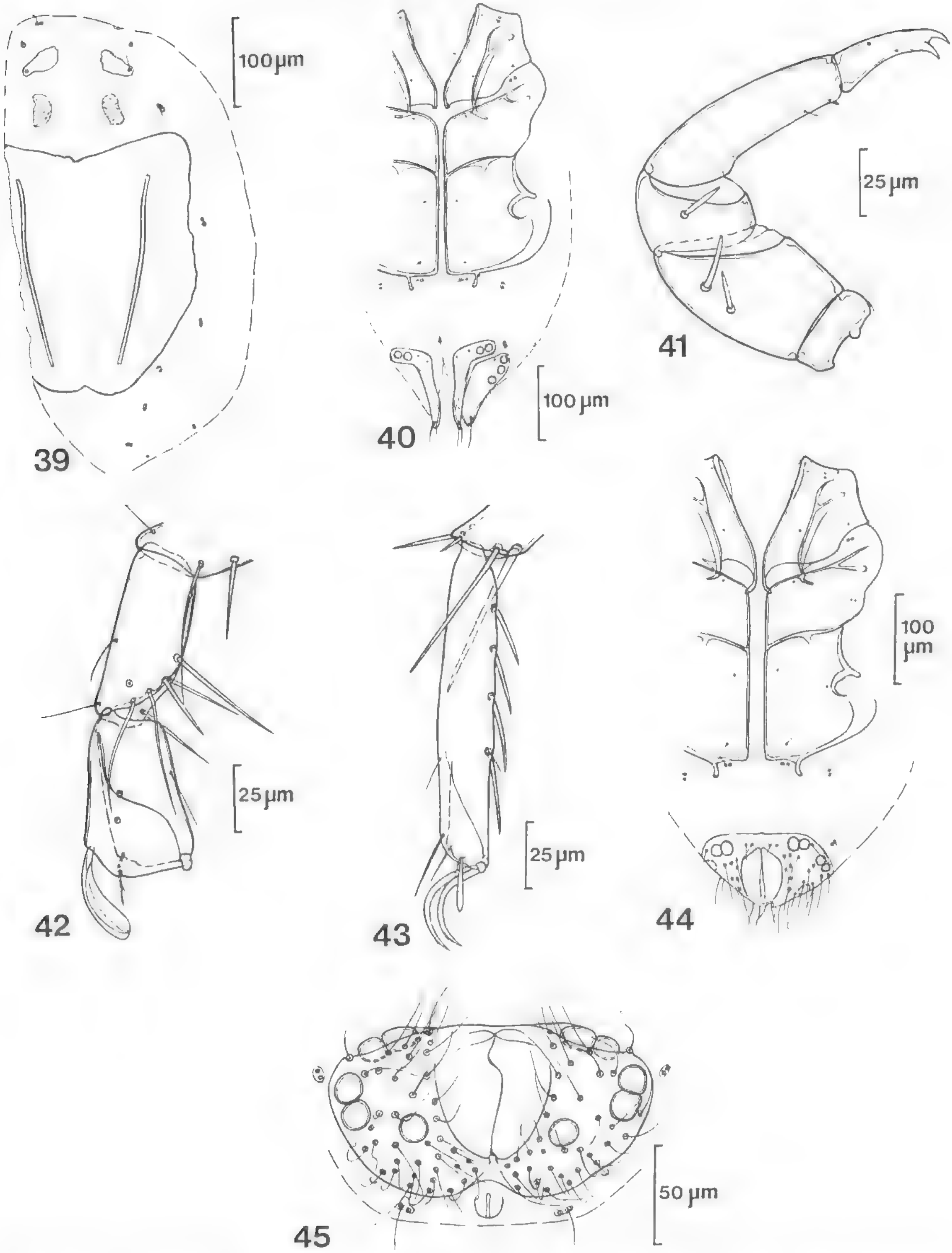
Capitulum 109(118) long and 70(75) wide. Palps are similar to ♀; dorsal segment lengths (left P I–V): 8(9) . 60(70) . 30(33) . 72(77) . —(41). Dorsal leg segment lengths: I.L.3–6: 55(58) . 85(89) . 64(67) . 67(68); IV.L.3–6: 62(67) . 102(110) . 128(136) . 116(121).

Host and locality: *Velesunio angasi* (Sowerby), Ja-Ja Billabong, Magela Creek, Arnhem Land, N.T., W. D. Williams, xi.1977 (2 ♂, 1 ♀, incl. holotype and allotype).

Remarks: Like *U.* (*P.*) *clipeata* n.sp., this species has an undivided dorsal shield in which borders have become fused. Essential differences between the two species are in Table 2.

Genus **Unionicolopsis** n.g.

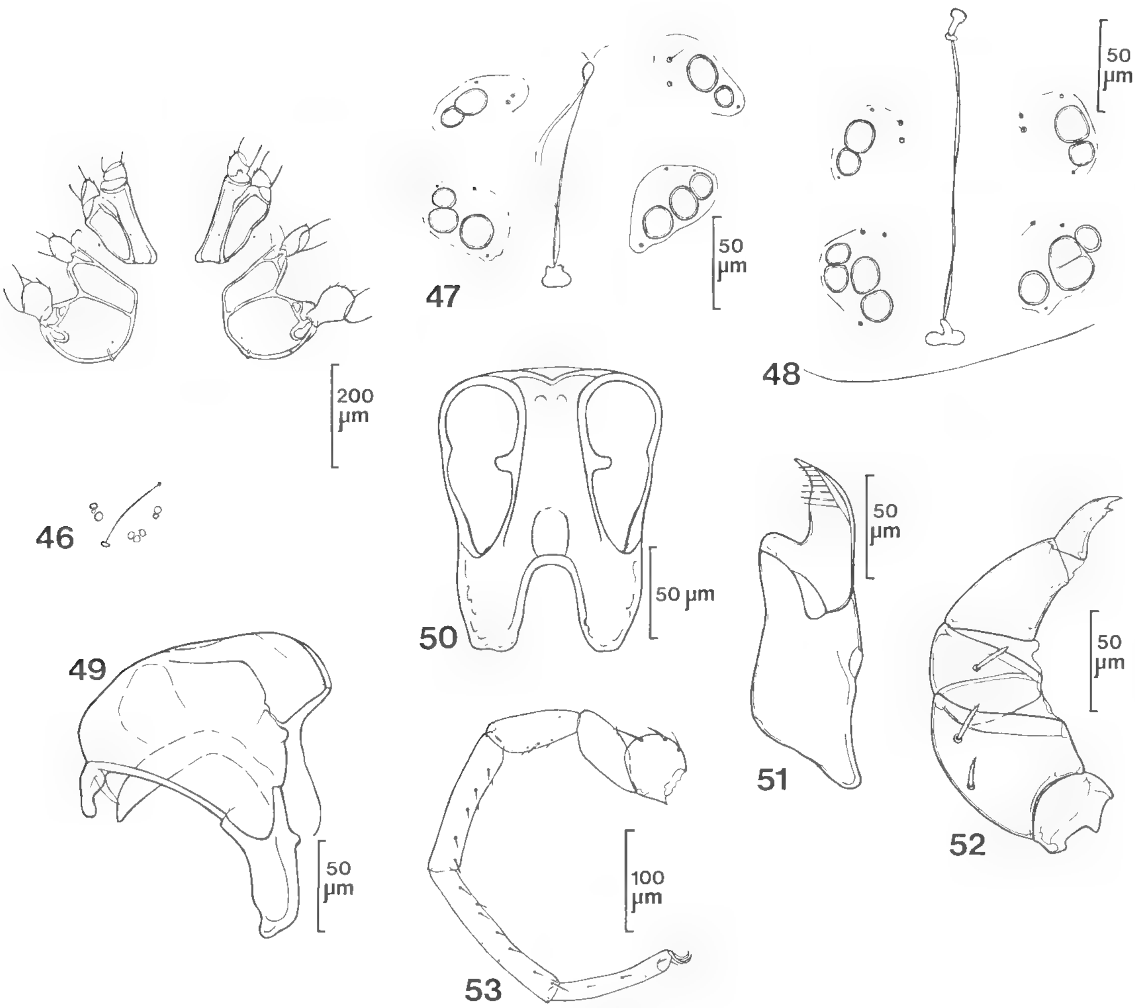
Diagnosis (based on ♀ only): With soft integument. Coxae in four groups, the posterior group especially widely separated; anterior coxal group without posterior apodemes. Genital field with delicate, weakly chitinized plates,



Figs 39–45. *Unionicola* (*Pentatax*) *scutata* n.sp. 39. ♀ holotype, prep. 6679, dorsum; 40. ♀ holotype, ventral side; 41. ♀ holotype, left palp; 42. ♀ holotype, I.L.5–6, left; 43. ♀ holotype. IV.L.5–6, right; 44. ♂ allotype, prep. 6680, ventral side; 45. ♂ paratype, prep. 6681, genital field.

TABLE 2. *Comparison of* U. (P.) scutata *and* U. (P.) clipeata

	U. (P.) scutata n.sp.	*U. (P.) clipeata* n.sp.
body size	large (330–380)	small (270–300)
dorsum	dorsal shield strongly chitinized; with a pair of small shields, each bearing hair-pore, in front of ant. muscle attachment sites	dorsal shield weakly chitinized; without shields in front of ant. muscle attachment sites
genital field	with many hair-pores	with few hair-pores
IV.L.6	with distal club-shaped structure	without distal club-shaped structure



Figs 46–53. *Unionicolopsis opimipalpis* n.sp. 46. ♀ holotype, prep. 6683, ventral side; 47. ♀ paratype, prep. 6684, genital field; 48. ♀ paratype, prep. 6682, genital field; 49. ♀ holotype, capitulum, lateral view; 50. ♀ paratype, pre. 6682, capitulum, dorsal view; 51. ♀ holotype, chelicera; 52. ♀ holotype, left palp; 53. ♀ paratype, prep. 6684, leg IV, left.

anterior plates each with two, posterior plates each with three, genital acetabulae. Medial margins of plates without special spines or setae. Capitulum with broad upper processes. Palp stout, without process on P IV.

Type species: Unionicolopsis opimipalpis n.sp.

Unionicolopsis opimipalpis n.sp.

FIGS 46–53

Holotype ♀ prep. 6683 (+ *paratype* ♀♀ preps. 6682, 6684): In soft dorsal integument is pair of long and pair of short muscle attachment sites; these are not significantly chitinized, and not formed as plates. Data for all three specimens are given (paratypes in parentheses).

Third and fourth coxae (Fig. 46) relatively widely separated in medial line; medial length about 148(145, 148). Posterior apodemes of first coxal group absent.

Genital plates (Figs 47–48) very weakly chitinized, and indistinct in outline; widely separated, on both sides of gonopore (c. 165 (165, 175) long). As in *Pentatax*, each anterior plate with two genital acetabulae, and posterior plates with three acetabulae. Number of acetabulae may vary (Fig. 48).

Capitulum (Figs 49–50) stout, about 164 (150, 163) long and —(119, 120) wide, and ends posteriorly in two wide-lobed, upper processes. Chelicerae 165 long (Fig. 51). Palps stout (Fig. 52), P II with two setae on inner and outer sides. No process on P IV. P V ends in two large, dissimilar claws.

Legs very simple in form. On I.L.3, in about middle of ventral side, is conspicuous, very long, strong seta, and beside it a short seta. On III.L.3 and 4 is distal seta and another proximally. Setae on segment 3 dissimilar in length, whereas those on segment 4 are about equal, and in general longer than those on segment 3. At distal extremity of III.L.5 pair of setae. IV.L.1 bears three distinct setae (Fig 53); all other segments of leg IV with only very small spine-like setae. Segments 4–6 on leg IV elongate, and segment 6 slightly curved. All tarsal claws simple. Dorsal leg segment lengths: I.L. 3–6: 59(59, 62) . 75(67, 75) . 72(65, 72) . 75(75, 79); IV.L.3–6: 103(99, 105) . 169(158, 173) . 187(179, 193) . — (154, 164).

Host and locality: Velesunio ambiguus, R. Murray nr Albury, N.S.W., T. J. Hillman, xi.1977 (3 ♀, incl. holotype).

Remarks: Only 3 ♀♀ of this new species are available and, because the ♂ remains unknown, the systematic position of the material is uncertain. Whether the new species, for which the *Unionicolopsis* n.g. now is erected, should be placed as a subgenus in *Unionicola*, must remain in doubt pending discovery of the ♂. It appears unlikely to me.

List of mussels and associated mites

Alathyria jacksoni Iredale: *U. (P.) walkeri, conjunctella, ligulifera.*

Velesunio ambiguus (Phillipi): *U. (P.) walkeri, conjunctella, ligulifera, procursa, clipeata; Unionicolopsis opimipalpis.*

Velesunio angasi (Sowerby): *U. (P.) scutata.*

Westralunio carteri Iredale: *U. (P.) assimilis.*

Key to the species of the Pentatax group described herein

1. Dorsum with undivided shield, with pair of distinct chitinous ridges ... 2
   Dorsum without complete shield ... 3
2. Shield strongly chitinized; IV.L.6 with distal club-shaped chitinous structure; first coxae of ♀ falling short of, those of ♂ extending beyond posterior apodemes ... *scutata*
   Shield weakly chitinized; IV.L.6 without distal club-shaped chitinous structure; first coxae of ♂ and ♀ not extending beyond posterior apodemes ... *clipeata*
3. Dorsum with two weakly chitinized plates, each having distinct chitinous ridge ... 4
   Dorsum without chitinized ridges, but with muscle attachment sites on weakly chitinized plates ... 6
4. Suture between third and fourth coxae reaching medial margin of posterior pair of plates; distal-dorsal edges of II. and III.L.6 with only slightly expanded (spoon-shaped) seta; first coxae of ♀ shorter than those of ♂, longer than posterior apodemes ... *conjunctella*
   Suture between third and fourth coxae not reaching medial margin of posterior pair of plates ... 5
5. II. and III.L.6 with setae only on distal-dorsal margin; first coxae of ♂ and ♀ not extending beyond posterior apodemes ... *assimilis*
   II. and III.L.6 with large spoon-shaped chitinous structure dorsally (as on I.L.6); first coxae of ♀ shorter than, and those of ♂ extending beyond posterior apodemes (reaching suture between third and fourth coxae) ... *ligulifera*
6. P V long (57.7–65.7% of P IV length); inner side of P II with 3 setae; IV.L.6 without club-like structure ... *procursa*
   P V short (45.7–51.9% of P IV length); inner side of P II with 2 setae; IV.L.6 with club-like structure (♀ genital field distinct from that of other species, with 4 similar plates and short, thick spines) ... *walkeri*

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BY C. R. TWIDALE

Summary

The Devil's Marbles consist of castle koppies (catellated inselbergs) and large residual boulders, both developed in granite. They are exposed in the core of an anticline outlined topographically by bevelled sandstone ridges. The major granite forms developed in two stages. Fracture-controlled differential compartment weathering beneath a late Mesozoic land surface was followed by stream incision and the erosion of the weathered bedrock. In this way the resistant essentially unweathered compartments and blocks were exposed and left in relief. The landscape in and near the Devil's Marbles is almost entirely the result of the erosional exploitation of the differentially weathered bedrock. The residuals are thus of etch character.

THE DEVIL'S MARBLES, CENTRAL AUSTRALIA

by C. R. TWIDALE*

Summary

TWIDALE, C. R. (1980) The Devil's Marbles, central Australia. *Trans. R. Soc. S. Aust.* 104(3), 41-49, 30 May, 1980.

The Devil's Marbles consist of castle koppies (catellated inselbergs) and large residual boulders, both developed in granite. They are exposed in the core of an anticline outlined topographically by bevelled sandstone ridges. The major granite forms developed in two stages. Fracture-controlled differential compartment weathering beneath a late Mesozoic land surface was followed by stream incision and the erosion of the weathered bedrock. In this way the resistant essentially unweathered compartments and blocks were exposed and left in relief. The landscape in and near the Devil's Marbles is almost entirely the result of the erosional exploitation of the differentially weathered bedrock. The residuals are thus of etch character.

The massive, simple, granite forms, largely lacking intricate fretting and sculpture, are typical of humid tropical regions rather than temperate lands, and stand in marked contrast with most of the granite landform assemblages of southern Australia.

Introduction

Though not as dramatic, large or famous as Ayers Rock and the Olgas, the groups of residual granite boulders known collectively as the Devil's Marbles are nevertheless well known and constitute a considerable attraction for tourists visting central Australia. Located astride the Stuart Highway about 50 km south of Tennant Creek, the residuals lie within 200 km of the geographical centre of Australia in central Mount Stuart (Fig. 1) and with an average annual rainfall of some 350 mm (13.7 inches) per annum are situated within the tropical semiarid zone of the continent.

Residual granite boulders are by no means rare. Granite comprises about 15% of the continental areas and apart from planation surfaces, boulders are the most common landform development on such outcrops. The Devil's Marbles are however unusual by virtue of the size of the boulders, their arrangement, and their detailed morphology. Many of the residual boulders are 11-12 m in diameter and at several sites these giant blocks stand in orderly arrangements so that they look like the remnants of Cyclopean masonry (Fig. 2). Technically they are castle koppies (rather than tors—see Twidale 1971). Other large boulders are precariously perched either on other blocks or boulders or on rock platforms; others stand in pairs, one on the other, to form cottage loaves; yet others have split in two as if sliced by some gigantic cleaver (Fig. 3).

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General setting

The granite on which the boulders are developed is a coarse-grained grey porphyritic muscovite-biotite adamellite, with large phenocrysts of feldspar. Radiometric (K/Ar) determinations give an age of about 1510 ma, i.e. the granite is Lower Proterozoic (Smith 1974). It intrudes Hatches Creek Group sediments, also of Lower Proterozoic age (Smith 1974) and is exposed in the core of an asymmetrical, plunging, anticlinal structure involving these sedimentary strata (Fig. 1). The structure is expressed topographically in a V-shaped outcrop of sandstone which is part of the Davenport Ranges and which borders the granite to both north and south. The sandstone ridge is bevelled. It stands some 490 m above sealevel and 70-80 m above the eastern lower valley floor, though only 30-40 m higher than the plains at the narrow western end of the lowland.

On the southwest the granite outcrop is drained by the headwaters of Sutherland Creek which flows south through a gorge in the sandstone ridge, but the greater part of the enclosed anticlinal valley drains north by way of Dixon Creek and its tributaries. The axial stream of the drainage system is situated at the western end of the valley and is in fact followed by the Stuart Highway. The major part of the granite outcrop lies east of the Highway so that there is a general decline in the altitude of the granite surface from east to west. The main groups of boulders are exposed near the Highway in the lowest part of the valley,

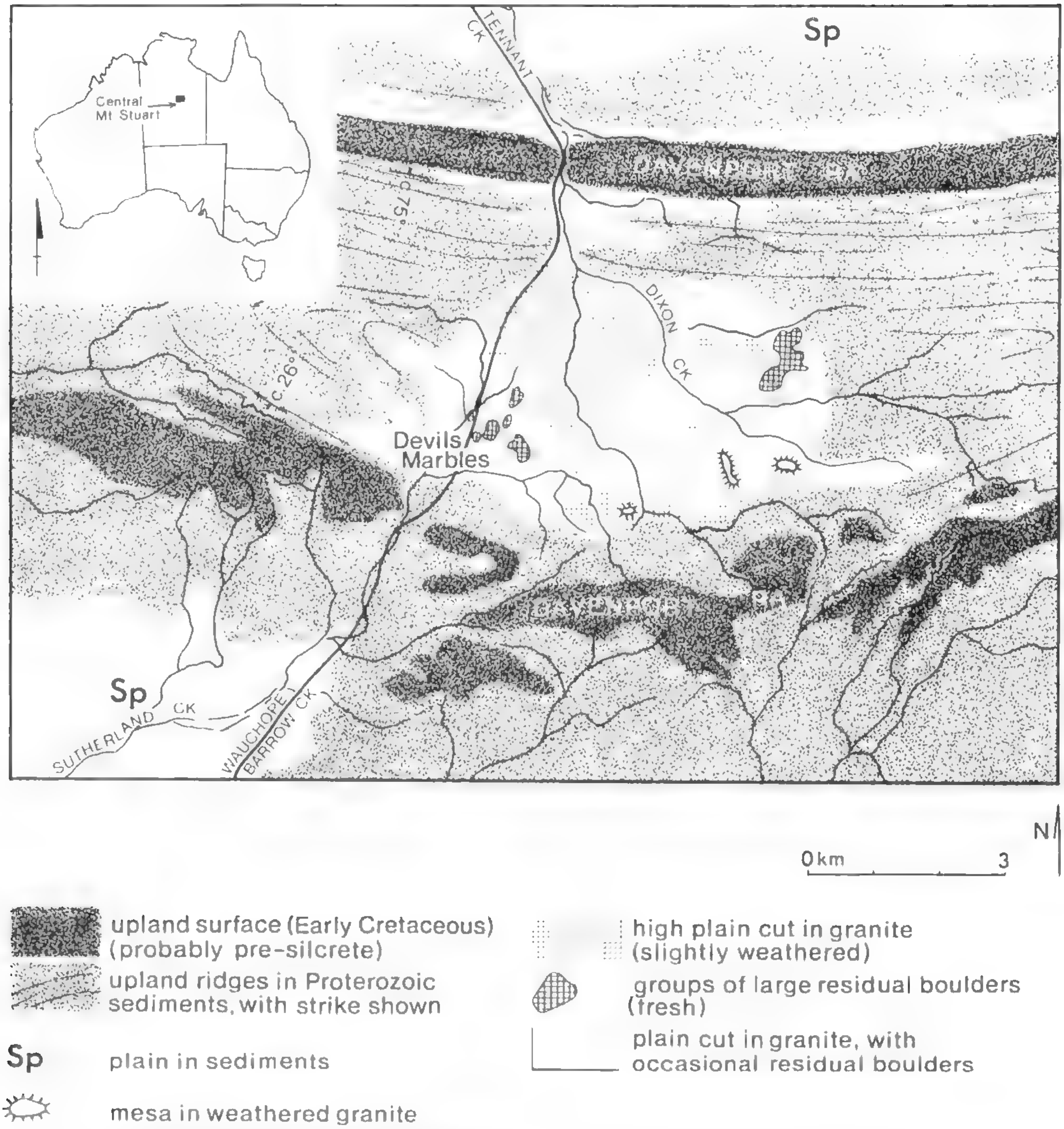


Fig. 1. Morphological map of Devil's Marbles and environs. Location map inset.

though there are others scattered over the plains (Fig. 1).

The surrounding hills and plains provide as much evidence concerning the evolution of these huge balls of rock as do the boulders and blocks themselves, and for this reason they are considered first.

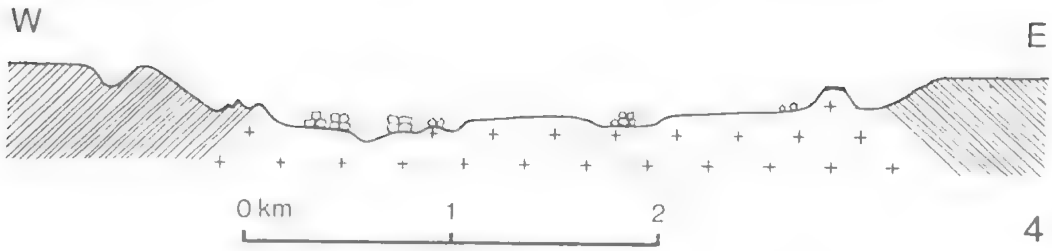
Planation surfaces

Plains of low relief are quite extensively developed on the granite outcrop and indeed occupy a far greater area than do the residual boulders. There are also remnants of two higher surfaces of low relief (Figs 1, 4).

The present plain is rolling or undulating and is shallowly dissected by numerous stream channels. It is eroded in granite that, though hard and cohesive is nevertheless weathered: the potash feldspar is generally white due to clay mineral alteration, the biotite is partly altered to chlorite, and there is abundant fracturing both along grain boundaries and across grains. Iron staining is obvious in thin section. The cut bedrock surface is covered by a few

Fig. 2. Castle koppie in Devil's Marbles complex consisting of massive quadrangular blocks, most *in situ*. The residual rises above valley floor beyond which is sandstone ridge with markedly bevelled crest.

Fig. 3. Split boulders at Devil's Marbles. Parallelism of fractures is noteworthy. Fractures can be traced through several boulders some tens of metres apart.



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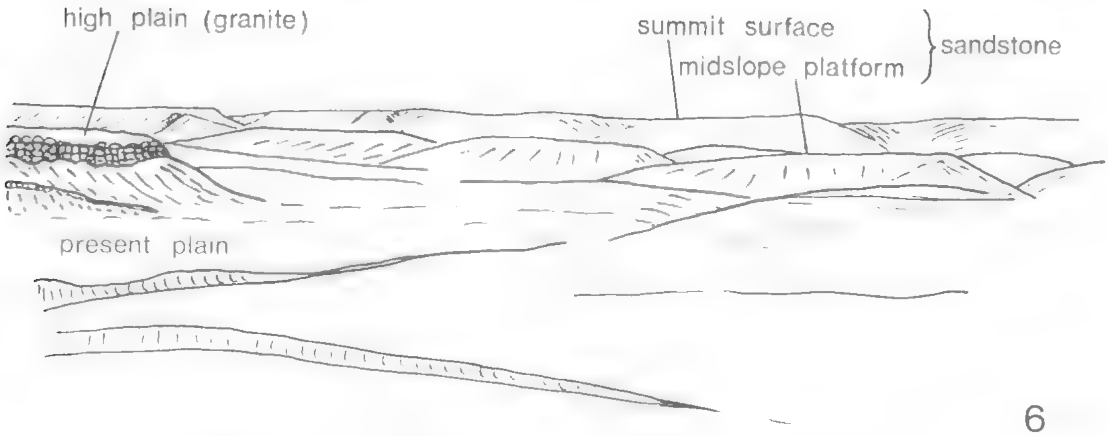

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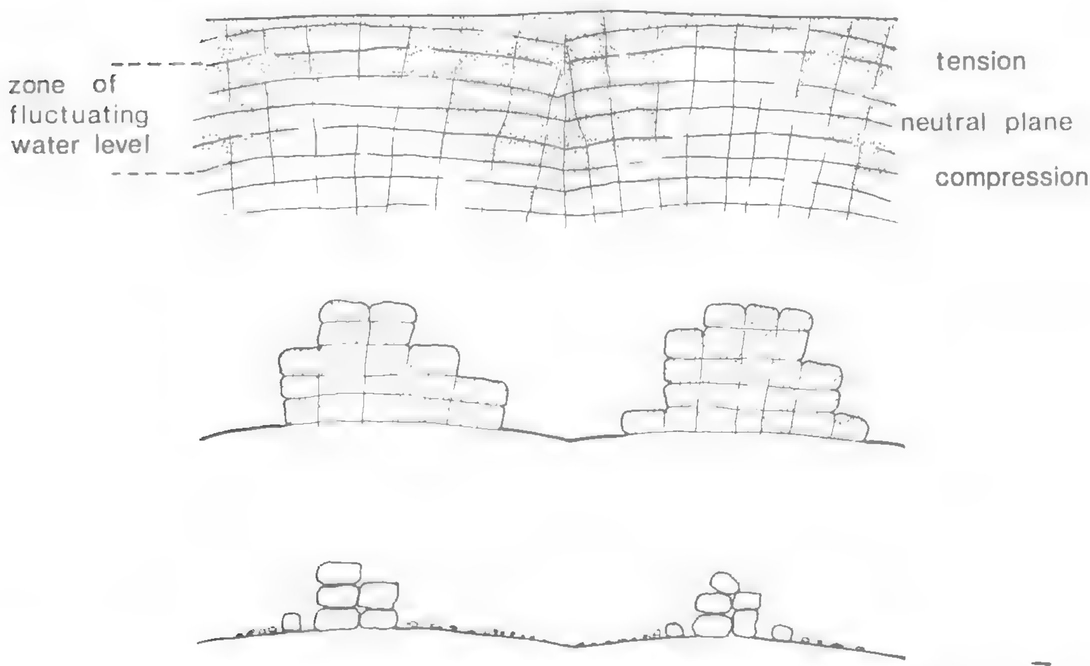

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Fig. 4. Diagrammatic cross-section through Devil's Marbles and adjacent areas.
Fig. 6. Field sketch of granite high plain and matching platform cut on slope of sandstone ridge.
Fig. 7. Two-stage development of Devil's Marbles. Dots indicate weathering.

centimetres of granite sand (quartz with fragments of feldspar and mica). Near the sedimentary outcrops at the margins of the plains small plates of sandstone are a significant constituent of the regolith, and in the vicinity of the few ridges underlain by quartz blows or reefs, white vein quartz is also abundant.

Small boulders and blocks stand above the general plain level in several areas. Their lower slopes are commonly roughened and fretted, or pitted (see Twidale & Bourne 1976), indicating recent, possible local, lowering of the soil surface of 20-25 cm. In addition the major granite forms known as the Devil's Marbles rise from this plain (Figs 1, 4).

Quite extensive remnants of a higher plain are preserved on the granite (Figs 1, 4). Bounded by rudimentarily faceted slopes up to 5 m high, this high plain carries a thin discontinuous veneer of granite sand. Granite platforms, with residual boulders and blocks, are also present. The granite exposed in this high plain is more weathered than that beneath the present plains. The potash feldspars are white due to partial kaolinisation, while the plagioclase has been strongly altered to an orange-brown clay, identified as kaolinite probably discoloured by goethite. The rock is extensively fractured as a result of weathering and iron oxide and clays are commonly found both in fissures and along crystal boundaries.

Standing 25-30 m above the high plain are three mesas capped by highly weathered granite. Quartz and muscovite are the only unweathered minerals, though the latter is altered along its cleavage. The rock samples appear to differ from the main mass of the outcrop and to be a greisen or primarily altered granite. The feldspars are completely altered to a brown orange kaolinite (again probably with goethite) which also fills intergranular spaces. The residuals are bounded by faceted slopes in which coarse blocks of granite are exposed (Fig. 5).

Both high plain and mesas can be correlated with planate features preserved on the sandstone ranges. Though standing a few metres lower, the mesa surface with highly weathered,

Fig. 5. Mesa in weathered granite standing above high plain level and with bevelled sandstone crest (with which the mesa surface is correlated) in background.

Fig. 8. Parted block at Devil's Marbles.

though still cohesive, granite can nevertheless reasonably be related to the prominent summit bevel of the Davenport Ranges (Figs 1, 4, 5). The high plain has its counterparts in a distinct platform developed and preserved at midslope on the inward-facing escarpments of the sandstone ridges (Fig. 6). Thus the landscape around the Devil's Marbles is multicyclic in character. Each of the two lower surfaces is contiguous over wide areas, and the three display different degrees of bedrock weathering; they are not identified solely on the basis of relative elevation.

Mabbutt (1967) has referred the summit surface of the Davenport Ranges on what he calls rather slight palaeogeographic evidence, to the later Mesozoic. This suggestion finds support in equivalents of the surface in the Barrow Creek and Alice Springs area standing higher, and being therefore older, than silcrete remnants of early-mid Tertiary age (Wopfner & Twidale 1967). The bevelled ridges of the Devil's Marbles region also stand higher than lateritised surfaces to the north, and as these also are of early-mid Tertiary age (Stewart 1954; Twidale 1956; Hays 1967), the later Mesozoic age of the summit surface is corroborated. The summit surface is in fact part of a later Mesozoic land surface of low relief that has been reported from several parts of tropical and subtropical Australia (see e.g. Woodard 1955; Twidale 1956, 1966, 1976a, 1980; Wright 1963; Mabbutt 1967; Hays 1967).

This summit surface and its equivalent in the mesas developed on granite is the datum to which the formation of the residual boulders can be referred, for all of the Devil's Marbles occur below it (Fig. 4). It is a weathering surface that has suffered leaching, strong kaolinsation above the weathering front or lower limit of significant weathering (Mabbutt 1961), and precipitation of iron oxides near and for some metres below this level.

Major granite forms

That the summit surface implies a period of relative standstill and weathering of the underlying bedrock is demonstrated by the altered granite preserved in the mesas. Had the granite been homogeneous there would have been uniform weathering beneath the plains surface, but the bedrock is jointed and although because of erosion it is not possible to discern what joint patterns had developed in the granite beneath the contiguous summit surface, there are indications that fracture spacing varies both vertically and laterally. For example whereas the joint blocks in some of the more prominent residuals are 10-12 m in diameter the joints exposed in creek beds nearby are only 20-30 cm apart. Again, the large residuals stand on plinths that are even more massive.

Observations in many parts of the world suggest very strongly that granite is subdivided into massive and well-jointed compartments. The latter are readily and rapidly weathered while the former remain intact. As the land surface is lowered the weathered rock is eroded, leaving the still-fresh and cohesive compartments in relief, as residuals the size and shape of which depends on fracture pattern (Fig. 7). Thus it is argued and has been urged for almost two centuries (see Hassenfratz 1791; Logan 1849, 1851; Mennell 1904; Twidale 1978a) that the granite residuals evolve in two stages, one involving differential joint-controlled subsurface weathering, the other the differential erosion of these unequally weathered compartments (Linton 1955; Büdel 1957; Wilhelmy 1958; Twidale 1971; Godard 1977).

In the case of the Devil's Marbles, differential compartment weathering took place beneath the late Mesozoic land surface represented by crestal bevels preserved on the sandstone ridges and by mesa remnants. The differential subsurface weathering took place during the later Mesozoic and early Cainozoic when this region, like the remainder of central Australia, was warm and humid to subhumid (Kamp 1978). The exposure of the koppies and boulders, on the other hand, is a later Cainozoic event probably related to regional warping and resultant stream rejuvenation.

In these terms the castle koppies are compartments characterised by widely spaced sets of orthogonal joints, though the flat-lying joints are almost certainly either the *Lagerklüfte* of Cloos (1922) or sheeting joints (Gilbert 1904; Twidale 1973). The residual boulders are large corestones or kernels remaining after the marginal weathered zones of the joint blocks have been eroded. The perched blocks and cottage loaves are to some extent fortuitous, though because weathering advances down from the surface it can be expected that more residuals will survive at depth than closer to the surface, so that in some places isolated blocks will come to stand on broader bases (Fig. 7).

The present plain is related to present local baselevel (Dixon Creek) and undoubtedly reflects a lowering of baselevel compared to later Mesozoic (summit surface) times. The high plain however could either be an etch surface or exposed weathering front (Wayland 1934), or it could be related to a baselevel intermediate between the summit surface and the present plains. The former interpretation appears the more likely, for the variations in granite weathering appear to be part of a single profile rather than two or more. The platforms previously noted (Fig. 6) on the inward-facing sandstone ridges, and interpreted as extensions of the high plain surface, could be of similar etch type and due to particularly intense moisture attack in the then scarp foot zone. Though the high plain slopes down to the west, the weathering front was probably irregular in detail because of variations in joint spacing and also because of the slope of the water table to the major water courses. The blocky upstanding koppies and large boulders, which were presumably once surrounded by well-jointed weathered rock, also stand on much broader, plinths or platforms of massive granite-compartments that survived to a much greater extent than those above them because they remained below the weathering front (Fig. 7).

Thus, the major landforms of the Devil's Marbles are readily comprehensible in terms of the two-stage concept. The residual remnants, though angular, probably represent dome structures developed as a result of compression in the crust (cf. Denham *et al.* 1979). They have been modified by aggressive weathering at depth and at the margins of the massive compartments, where ground waters persist: and in contrast with the near-surface drier, or seasonally dry, zones.

The minor forms

The boulders, blocks, and large-radius domes are fretted and sculptured in detail, though the resultant modifications are in most instances minor. Some blocks and particularly some of those high on residuals are both impregnated with iron and manganese oxide and greatly fretted and hollowed (alveolar weathering). Polygonal patterns of surface cracks are developed in these impregnated zones. These weathering phenomena argue the presence of water and the zones of intense attack may be related to former fluctuating water tables. On the other hand similar intense fretting is found at some sites at the bases of blocks and boulders, close to the old weathering front, and again abundant water is suggested as the reason for the especially aggressive weathering.

Some large boulders are elongate and streamlined and are called whalebacks or *dos de baleine*. A few large blocks have seemingly moved laterally relative to one another (Fig. 8), rather like the parted blocks described from Dartmoor (Worth 1953). Many blocks are split into two parts (Fig. 3). Some secondary joints have been exploited by weathering to form shallow straight grooves (*Kluftkarren*), though there are on some domes true *Rille* (*Echtkarren*) due to stream erosion. Some of them are coated with a black compound, consisting of carbon plus oxides of iron and manganese (Francis 1921). Similar coatings on granite occur in former pools in creek beds, indicating that this black material has been deposited from water. These black colours are however, unusual, for virtually all of the residuals carry a patina of reddish-brown iron oxide which effectively masks the grey colour of the granite seen in creek beds and where there has been fire flaking. Scaling of the rock surface is general, and pitting, due to differential weathering of surface crystals leaving quartz in microrelief has been noted on lower slopes. Rock platforms in places display regular patterns of vertical joints so that the whole looks like a pavement. At some sites the joints are weathered and there are minor flared slopes developed in the sidewalls of the clefts so formed.

Basal fretting has already been referred to and some boulders display poorly developed flared slopes. A few basal tafoni have been noted, but it is because of the virtual absence of this and other forms (flares, gnammas or weather pits, gutters or *Rille*) that the Marbles stand in such contrast with granite exposures in southern Australia (see Twidale 1971, 1976b; Twidale & Foale 1972).

The origin of most of these minor landforms is well known and is adequately discussed elsewhere (Wilhelmy 1958; Twidale 1971, 1976b; Twidale & Foale 1972; Twidale & Bourne 1975).

Several lines of evidence point to the minor forms having been initiated by moisture attack, in the subsurface, at the weathering front. Incipient pitting, flared slopes, platforms, tafoni, saucer-shaped depressions and gutters have been observed already developed on the bedrock surface when the regolithic cover was

stripped away and some forms, particularly *Rille*, can be traced into the subsurface (Logan 1851; Twidale 1962, 1971, 1976b, 1978b; Boyé & Fritsch 1973; Twidale & Bourne 1975, 1976, 1977). The cover is weathered granite *in situ*, not introduced material, so that there is no question of the minor features developed in granite having been formed on exposed surfaces and then buried. The forms are modified—either developed or destroyed—after exposure, but they are initiated in the subsurface.

Only three of the minor landforms call for further brief comment. First, with regard to parted blocks, Worth (1953) rightly discounted gravity, for the blocks stand on flat or very gently sloping inclines. Ice or nival action can be discounted at the Devil's Marbles, and shaking by earthquakes seems unlikely, for not only is the area siesmically quiet but had there been earth tremors sufficient to dislodge the parted blocks, no perched boulders would surely have survived.

Second, split rocks have been attributed by several writers to heating and cooling under desert conditions (e.g. Hume 1925; Hills 1975). It is very doubtful whether this process alone, or even aided by the cooling effect of rain showers, could achieve the splitting of such massive bodies of rock. Furthermore split rocks are even more common in nival regions (e.g. the Pyrenees) than they are in arid areas. It is suggested that three factors are involved. Though the boulders and blocks that are split are basically defined by orthogonal joints, it is a matter of observation that many include other, presumably secondary or latent joints (Fig. 3). These subsidiary fractures are exploited by weathering processes and notably by water in either liquid or solid form, depending on climatic conditions. Finally once weathering has sufficiently affected the subsidiary fracture and provided it is vertically or near-vertically disposed, the weight of the two halves will cause the weakened fracture to be pulled apart, so creating the split rock.

Third, polygonal cracking is clearly not a primary rock feature as suggested by some writers (Johnson 1927; Leonard 1929), for it is developed on boulders which are themselves the product of differential subsurface weathering. At Devil's Marbles and in the Pilbara of Western Australia it has been noted that polygonal cracking is associated with rock that is heavily impregnated with iron and manganese oxides. In the Pilbara, near Mount Magnet and on Eyre Peninsula the cracking frequently affects two or more superimposed layers of rock, and some of the plates delineated by the cracks are arched slightly upwards. Various mechanisms have been considered and found wanting. The most likely is that salts of iron and manganese which are mobile are carried in groundwaters and precipitated out near the weathering front, i.e. near the margins of the boulders whilst they are still corestones and beneath the land surface. The continued precipitation of salts causes the buckling of the rock in the direction of least resistance, namely outwards and the fracturing of the shells into polygonal plates.

Lastly it is emphasised that the Devil's Marbles are simple groups of residual boulders, lacking any great variety or development of minor forms. With regard to the latter, the forms that are absent, or virtually so, are as interesting as those that are present. Thus, flared slopes, tafoni, *Rille* and rock basins are rare or poorly developed. In this respect the Devil's Marbles are more akin to the tropical granite exposures of northwest Queensland, the Pilbara and the Darwin area rather than those of the temperate, particularly the Mediterranean environments of much of South Australia, southern Victoria and the Wheat Belt of Western Australia. This is not to suggest either that flared slopes for instance are not found in the northern areas (though they are rare and poorly developed there) or that they have evolved to a spectacular degree on all southern outcrops. Many factors are involved and in many respects it is not a simple question of development or non-development, but rather of degree of development and preservation. Nonetheless, zoned contrasts are discernible and the Devil's Marbles both in gross and in detail have more affinities with the humid tropics than with the temperate and Mediterranean lands of southern Australia.

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FURTHER OBSERVATIONS ON SPERMATOZOAL MORPHOLOGY AND MALE REPRODUCTIVE TRACT ANATOMY OF PSEUDOMYS AND NOTOMYS SPECIES (MAMMALIA: RODENTIA)

BY W. G. BREED

Summary

Spermatozoa of Notomys cervinus have a head with three hooks, whereas those from N. fuscus are variable but have only two very short hooks. Spermatozoa from Pseudomys forresti, P. fumeus, and P. gracilicaudatus all have a head with three hooks. Only one very short hook occurs in P. novaehollandiae, and there are no hooks in spermatozoa from P. delicatulus, P. shortridgei has a spatulate sperm head with a large acrosome. Insertion of the sperm tail is lateral in novaehollandiae, offset basal in P. delicatulus and mid-basal in P. shortridgei. Principal and end pieces are shorter in the last two species.

FURTHER OBSERVATIONS ON SPERMATOZOAL MORPHOLOGY AND MALE REPRODUCTIVE TRACT ANATOMY OF *PSEUDOMYS* AND *NOTOMYS* SPECIES (MAMMALIA: RODENTIA)

by W. G. BREED*

Summary

BREED, W. G. (1980) Further observations on spermatozoal morphology and male reproductive tract anatomy of *Pseudomys* and *Notomys* species (Mammalia: Rodentia). *Trans. R. Soc. S. Aust.* 104(3), 51-55, 30 May, 1980.

Spermatozoa of *Notomys cervinus* have a head with three hooks, whereas those from *N. fuscus* are variable but have only two very short hooks. Spermatozoa from *Pseudomys forresti, P. fumeus,* and *P. gracilicaudatus* all have a head with three hooks. Only one very short hook occurs in *P. novaehollandiae,* and there are no hooks in spermatozoa from *P. delicatulus. P. shortridgei* has a spatulate sperm head with a large acrosome. Insertion of the sperm tail is lateral in *P. novaehollandiae,* offset basal in *P. delicatulus* and mid-basal in *P. shortridgei.* Principal and end pieces are shorter in the last two species.

Notomys alexis, N. fuscus, and *N. mitchellii* have very small testes, whereas they are relatively larger and scrotal in *N. cervinus.* In the first three species seminal vesicles and coagulating glands are vestigeal or non-existent, whereas in *N. cervinus* they are well developed and weigh up to 150 mg. The possible phylogenetic and functional significance of these differences is discussed.

Introduction

Phylogenetic relationships between different species of rodents have been investigated by a variety of techniques, all of which have at least some limitations. In several groups of North American and British myomorph rodents spermatozoal morphology and comparative anatomy of the male accessory sex glands have been used (Friend 1936, Bishop & Walton 1960, Arata 1964, Linzey & Layne 1969, 1974). The latter authors concluded that in *Peromyscus* variation in accessory sex glands corresponded well with major taxonomic groupings based on other criteria, whereas variation in spermatozoal morphology did not coincide with the subgeneric groups. Breed & Sarafis (1979) extended a brief report by Illison (1971)[1]; investigated spermatozoal morphology and male reproductive tract anatomy in some species of Australian rodents, and discussed phylogenetic relationships between various genera. They found that within each genus similar spermatozoal morphology occurred apart from *Notomys*. Illison (1971)[1] reported that *Pseudomys shortridgei* has a primitive sperm type, and *P. delicatulus* (as *Leggadina delicatula*) a spermatozoal head with no hooks, so it appears that *Pseudomys* exhibits considerable spermatozoal diversity: all five species that we investigated had a sperm head with three hooks. Male accessory sex glands were generally similar between the genera investigated, apart from the two species of *Notomys* which differed markedly (Breed & Sarafis 1979). Here spermatozoal morphology of six other *Pseudomys* and two other *Notomys* species is presented, together with an examination of the male reproductive tract from all four *Notomys* species.

Materials and methods

Spermatozoa were obtained from single adult male individuals of the following species housed at the Institute of Medical and Veterinary Science (I.M.V.S.), Adelaide.

Notomys cervinus: Born at University of N.S.W., received 10.IV.79; *N. fuscus:* Laboratory bred at I.M.V.S., *Pseudomys delicatulus:* collected at Shortcut Rd, Nourlangie, N.T. (I.M.V.S. publ. 1017); *P. forresti:* received from University of N.S.W., 10.IV.79 (I.M.V.S. publ. 953); *P. fumeus:* from Arthur Rylah Institute, Melbourne (I.M.V.S publ. 952); *P. gracilicaudatus:* from School of Biological Sciences, Macquarie University (I.M.V.S. publ. 950); *P. shortridgei:* from Fisheries and Wildlife Division, East Melbourne (I.M.V.S. publ. 951).

In all individuals a small incision was made into the region of the tail of the epididymis under halothane anaesthesia, and a small biopsy taken. Spermatozoa were then squeezed out onto microscope slides previously flooded

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[1] Illison, L. Abstract of paper presented at Aust. Mammal Soc. Meeting vol. 2, No. 8, Dec. 1971.

with glutaraldehyde/formaldehyde/picric acid fixative (see Ito & Karnovsky 1968). Semi-permanent mounts were made by placing a coverslip on top of the sperm and ringing the mount with DePeX. Subsequently the sperm were photographed with Nomarski optics at CSIRO Division of Horticultural Research, Glen Osmond. Measurements were made of several spermatozoa from each species under phase contrast using an eyepiece micrometer as described by Breed & Sarafis (1979). Although difficulty was experienced in obtaining accurate measurements, the mean values for head length, midpiece, and principal together with endpiece were determined.

Adult male individuals of *Notomys mitchellii, N. alexis, N. cervinus* and *N. fuscus* collected in the field (1960-1978), preserved in formalin or 70% alcohol, and lodged at the S.A. Museum, W.A. Museum or I.M.V.S., were weighed. A single testis, seminal vesicles with coagulating glands, and ventral prostates were dissected out, cleared of adherant fat, subsequently weighed and, where appropriate, measured. The testis weight was subsequently doubled to give the approximate weight of paired testes. A few laboratory bred adult *Notomys* held at I.M.V.S. or Medical School, University of Adelaide, were also killed and male reproductive tracts dissected out and weighed. A single *N. cervinus* (provided by Mr R. Briggs) was weighed, dissected and investigated similarly.

Results

Table 1 and Fig. 1 present morphological details of spermatozoa determined by light microscopy. Sperm of *P. forresti, P. fumeus,* and *P. gracilicaudatus* had a head with three hooks, although the size of the sperm head and length of hooks was greater in *P. gracilicaudatus*. The sperm head of *P. novaehollandiae* had a single short top hook and a truncated or non-existent lower hook. That of

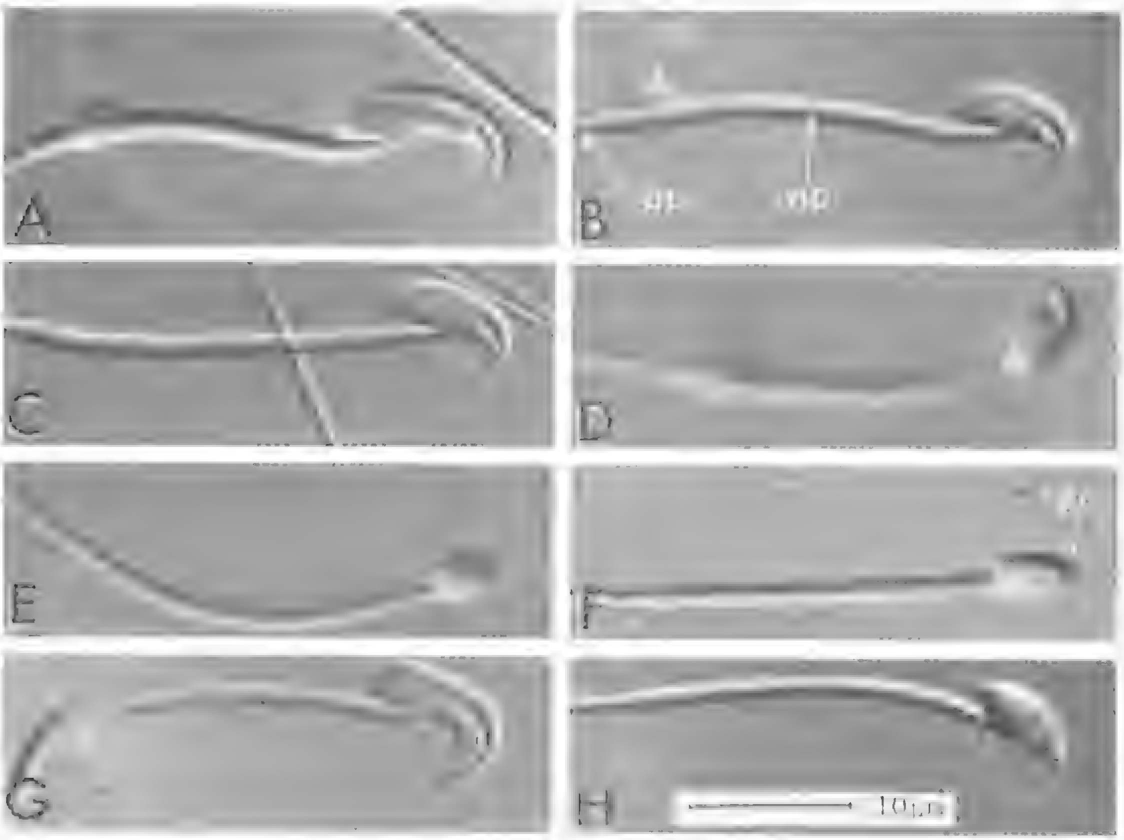

Fig. 1. *Spermatozoa.* A: *Pseudomys gracilicaudatus*; B: *fumeus*; C: *P. forresti*; D: *P. novaehollandiae*; E: *P. delicatulus*; F: *P. shortridgei*; G: *Notomys cervinus*; H: *N. fuscus*. mp = middle piece, pp = principal piece, ac = acrosome, cd — cytoplasmic droplet.

TABLE 1: head and tail length of spermatozoa from various *Notomys* and *Pseudomys* species.

Species	*Average size of spermatozoa (μm)*			
	Head	*Midpiece*	*Principal and endpiece*	*Total*
Notomys fuscus	7	22	77	106
N. cervinus	9	26	80	115
Pseudomys delicatulus	4	19	65	88
P. forresti	7	26	95	128
P. fumeus	8	20	100	128
P. gracilicaudatus	10	21	98	129
P. novaehollandiae	6	22	78	106
P. shortridgei	5	22	69	96

P. delicatulus had no hooks and was smaller than the others. *P. shortridgei* also had sperm with no visible hooks. It was spatulate in shape, and a large acrosome occurred over the nucleus. The principal and endpieces were shorter in the last two species.

Notomys fuscus had variable sperm head morphology, but usually there were very short and truncated top and lower hooks. *N. cervinus* sperm had a head with a long top hook and two lower hooks united at their base.

In wild caught *N. alexis* testes weight ranged from a mean of 20-37 mg with time of year. Often no obvious scrotum was discernible. Seminal vesicles were at most only just visible in the preserved material and did not exceed 3 mm length. Coagulating glands and dorsal prostates were vestigeal or non-existent. Large ventral prostates occurred which varied in weight during the year; no seasonal trend was apparent. Laboratory bred adult *N. alexis* have similar reproductive tract anatomy (Breed 1979, Breed & Sarafis 1979).

Similar male reproductive tract morphology occurred in *N. mitchellii* and *N. fuscus* (Table 2). By contrast, that of *N. cervinus* was markedly different (Table 2, Fig. 2). The testes were relatively larger and scrotal in position, although adult body weights were similar to the other species. Conspicuous seminal vesicles and coagulating glands were present; their average weight being about 130 mg and length about 10 mm.

Discussion

The suggestion by Breed & Sarafis (1979) of intrageneric differences in spermatozoal morphology and male reproductive anatomy in *Pseudomys* and *Notomys* has been confirmed. Most *Pseudomys* and two of four species of *Notomys* have spermatozoa with three hooks. In *P. novaehollandiae* there appears to be only one short truncated hook, and all three hooks are missing in spermatozoa from *P. delicatulus* and *P. shortridgei*. Preliminary transmission electron microscopy (TEM) has confirmed a large, somewhat eccentrally placed, acrosome

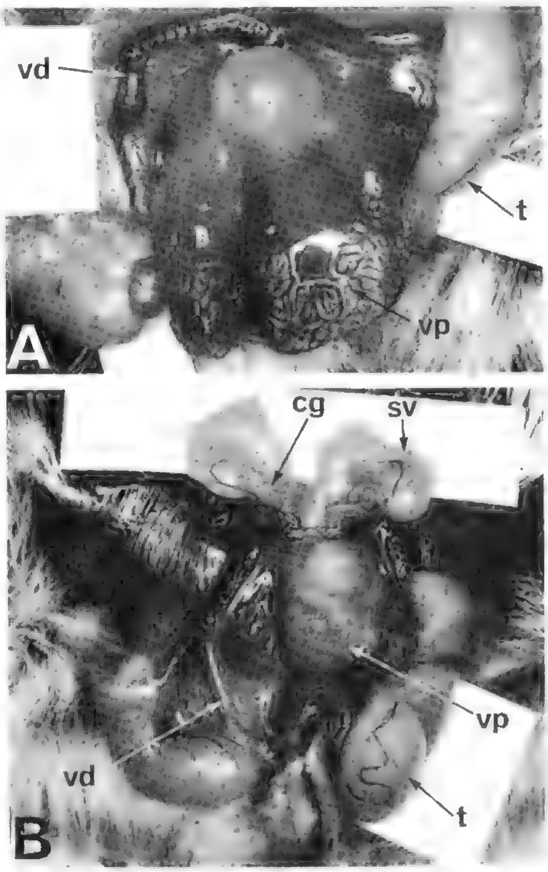

Fig. 2. *Male reproductive tracts.* A: *Notomys mitchellii;* B: *N. cervinus.* t = testis, sv = seminal vesicle, vp = ventral prostrate, cg = coagulating gland, vd = vas deferens.

TABLE 2: Adult reproductive organ weights of male *Notomys* (mean ± S.E.)

	No. of animals	Body wt (g)	Testis wt (mg)	Ventral prostrate wt (mg)	Seminal vesicle & coagulating gland wt (mg)
Notomys alexis					
Fixed tissue					
Month of capture					
Jan & Feb	6	20****	22 ± 4	62 ± 26	—*
Mar & Apr	16	30 ± 0.5	31 ± 6	84 ± 6	
May & June	19	30 ± 3	37 ± 4	77 ± 9	
July & Aug	18	30 ± 3	22 ± 3	55 ± 2	
Sept & Oct	4	31 ± 3	30 ± 1	125 ± 30	
Nov & Dec	3	37****	31 ± 11	98 ± 26	
Fresh tissue †	3	28 ± 2.6	38 ± 3	89 ± 8	—*
***	4	29 ± 2	33 ± 9	97 ± 20	
Notomys mitchellii					
Fixed tissue	13	39 ± 2	50 ± 3	162 ± 21	—*
Fresh tissue	3	48 ± 2	78 ± 7	407 ± 223	
Notomys fuscus					
Fixed tissue	9	28 ± 2	43 ± 4	58 ± 17	—*
Notomys cervinus					
Fixed tissue	12	38 ± 2	133 ± 8	78 ± 7	130 ± 21 (10 ± 0.7)*****
Fresh tissue	1	32	170	103	150 (11)*****

* Vestigeal or non-existent: maximum length of seminal vesticlaes — 3 mm.
† From Breed 1979 (80 days of age).
*** From Breed & Sarafis 1979.
**** Body wt of only one animal recorded.
***** Length of seminal vesicles (mm) given in parenthesis.

in *P. shortridgei*, and a few cup-shaped evaginations in the apical part of the nucleus. In *P. delicatulus* the acrosome appears considerably different and somewhat complex in structure.

TEM has also shown that the connecting piece of the tail in *P. shortridgei* has a mid-basal insertion into the sperm head, an offset basal insertion in *P. delicatulus* and a lateral insertion in *P. novaehollandiae* and other species with the more typical sperm head morphology. *N. fuscus*, *N. alexis*, and *N. mitchellii* all appear to have somewhat variable sperm head morphology and the former two species truncated, or nonexistent, hooks (see also Breed & Sarafis 1979).

Most non-Australian murid rodents investigated have a sperm head with a single top hook (vide Friend 1936, Bishop & Walton 1960), whereas most species of Australian rodents have sperm heads with at least two, and usually three, hooks (Illison 1971, Breed & Sarafis 1979). It seems plausible that some ancestral, non-Rattus, murid rodent evolved a sperm head with this complex structure, and that adaptive radiation of the group within Australia then occurred, most species maintaining this specialised sperm head morphology. The reduction, or lack of, hooks in the few *Notomys* and *Pseudomys* species is, therefore, probably a recently derived state. Variability in sperm head morphology in the two *Notomys* species with truncated hooks may support this contention.

The anatomy of the male accessory sex organs of *Pseudomys* investigated is similar, regardless of the differences in spermatozoal morphology. There are relatively large 'leaf-like' seminal vesicles 6.5 mm or more in length in *P. gracilicaudatus* and *P. australis* (Taylor & Horner 1972), *P. hermannsburgenesis* (Taylor & Horner 1970), *P. apodomoides*, *P. forresti*, *P. novaehollandiae*, and *P. delicatulus* (Breed, unpublished). Taylor & Horner (1972) state that no coagulating glands follow the posterio-lateral contour of the seminal vesicles in *P.*

australis, but that in laboratory-bred animals such glands were found, and the mixing of secretions of seminal vesicles and coagulating glands results in the occurrence of hard gelatinous material. Vaginal plugs, which in common laboratory rodents result from a mixture of secretions from seminal vesicles and coagulating glands (Mann 1964), have been recorded in laboratory bred *P. australis* (Smith, Watts & Crichton 1972).

In *Notomys* considerable inter-specific differences occur in accessory sex gland and testicular development. *N. cervinus* has the typical complement of male accessory sex glands, whereas in the other species the seminal vesicles, coagulating glands, and dorsal prostates are vestigeal or non-existent. *N. cervinus* is also the only species of *Notomys* for which a vaginal plug has been recorded (Crichton 1974) and it also has typical scrotal testes, whereas they are relatively much smaller and perianal in position in the others. Lack of testicular development presumably results in the absence of an obvious scrotum that often occurs in these species.

The above findings indicate, therefore, that spermatozoa and the male accessory sex glands are somewhat labile structures, as considerable variation occurs within *Notomys* that, on other morphological and physiological grounds, appears to be a discrete and closely related group. Since *N. cervinus* has the more conventional pattern of male reproductive tract anatomy, the occurrence of the vestigeal glands, very small testes, and the apparent lack of vaginal plug formation in the other three species is likely to be a recently derived state. The functional significance of these differences has yet to be elucidated, but it may be significant that relative testis size appears to correlate with seminal vesicle and coagulating gland development. Perhaps in species with relatively small testes, fewer sperm are produced, stored, and thus released at ejaculation. Less energy, and therefore seminal fluid, would thus be required for their metabolism in the female reproductive tract. This, in turn, may result in atrophy of some of the glands involved in the production of seminal fluid. Why such divergence should evolve in a closely related group of species is, at present unknown, but a study on the sexual and social behaviour of these animals is being carried out, and this may shed some light on the significance of these observed anatomical differences.

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FOSSILFEROUS LOWER DEVONIAN BOULDERS IN CRETACEOUS SEDIMENTS OF THE GREAT AUSTRALIAN BASIN

BY R. B. FLINT, G. J. AMBROSE & K. W. S. CAMPBELL

Summary

During 1977-78, 32 fossilferous Lower Devonian quartzite boulders were discovered within Mesozoic sediments along the southwestern margin of the Great Australian Basin. Previously only two such specimens had been discovered in South Australia though similar occurrences have been known in New South Wales since 1898. Fossils not previously recorded in S.A. include the fish Wuttagoonaspis, the brachiopods Howellella jaqueti and Sphaerirhynchia sp.; the bivalves Leptodesma inflatum, Sanguinolites sp. and Praectenodonta sp.; the gastropod Strapollus culleni; and abundant tentaculitids. Similar fossiliferous Devonian rocks are not known in situ in S.A. The probable source area is the fossilferous Amphitheatre and Mulga Downs Groups near Cobar in N.S.W. It is suggested that boulders were transported to S.A. during the Permian glaciation and then reworked into Cretaceous bouldery shales and sands. All but two of the boulders are found within conglomeratic sediments at the base of the Bulldog Shale. Theories on transport processes during the Cretaceous are discussed; it is concluded that conglomeratic sediments at the base of the Bulldog Shale are reworked submarine debris-flow deposits.

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Summary

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During 1977-78, 32 fossiliferous Lower Devonian quartzite boulders were discovered within Mesozoic sediments along the southwestern margin of the Great Australian Basin. Previously only two such specimens had been discovered in South Australia though similar occurrences have been known in New South Wales since 1898. Fossils not previously recorded in S.A. include the fish *Wuttagoonaspis*, the brachiopods *Howellella jaqueti* and *Sphaerirhynchia* sp.; the bivalves *Leptodesma inflatum*, *Sanguinolites* sp. and *Praectenodonta* sp.; the gastropod *Straparollus culleni*; and abundant tentaculitids. Similar fossiliferous Devonian rocks are not known *in situ* in S.A. The probable source area is the fossiliferous Amphitheatre and Mulga Downs Groups near Cobar in N.S.W. It is suggested that boulders were transported to S.A. during the Permian glaciation and then reworked into Cretaceous bouldery shales and sands. All but two of the boulders are found within conglomeratic sediments at the base of the Bulldog Shale. Theories on transport processes during the Cretaceous are discussed. It is concluded that conglomeratic sediments at the base of the Bulldog Shale are reworked submarine debris-flow deposits.

Introduction

Fossiliferous Devonian quartzite boulders from Cretaceous sediments were first described from White Cliffs Opalfield in N.S.W. by Dun (1898). P. J. Russ collected the first fossiliferous boulder in S.A. in 1966 from an opal shaft at the Andamooka Opalfield. It was thought at the time that an opal miner may have brought the boulder to S.A. from White Cliffs. However, after discovery of a second fossiliferous boulder near Dalhousie Springs by M. C. Benbow, the geological implications were assessed by Campbell *et al.* (1977). They concluded that the fossiliferous boulders, like those at White Cliffs, were derived from the Devonian Amphitheatre Group near Cobar in N.S.W., and that they were transported to S.A. during the Permian glaciation, later to be reworked into Cretaceous strata.

During geological mapping of the BILLA KALINA 1:250 000 map sheet and subsequent investigations elsewhere along the margin of the Great Australian Basin, a further 32 fossiliferous boulders were discovered, containing many species not previously recorded in S.A. Their occurrence and distribution permit a new assessment of their probable origin and modes of transport. The earlier concept of Campbell *et al.* (1977) is substantiated.

Geological setting

Stratigraphic units in the southwestern Great Australian Basin include the Algebuckina Sandstone, Cadna-owie Formation and Mount Anna Sandstone Member, Bulldog Shale and overlying younger Mesozoic sediments (Fig 1). The stratigraphic nomenclature adopted here is that of Wopfner *et al.* (1970) based on the Oodnadatta-William Creek area (for the Marree area see Forbes 1966).

The following geological summary is compiled from Wopfner & Heath (1963), Ludbrook (1966, 1978), Wopfner *et al.* (1970), Morgan (1977), Carr *et al.* (1978)[1], Pitt (1978), Vnuk (1978)[2] and from observations during geological mapping of the BILLA KALINA 1:250 000 map sheet.

The Upper Jurassic Algebuckina Sandstone consists of fine to medium-grained sandstones and kaolinitic, conglomeratic sandstone. Clasts within the conglomeratic sandstones are chiefly

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[1] Carr, S. G., Olliver, J. G., Conor, C. H. H. & Scott D. C. (1978) Andamooka Opal fields: The geology of the precious stones field and the result of the subsidised mining programme. S. Aust. Dept Mines & Energy Rept 78/5 (unpublished).

[2] Vnuk, M. F. (1978) Aspects of the geology of the Stuart Creek area, north of Lake Torrens, South Australia. B.Sc. (Hons.) thesis, University of Adelaide (unpublished).

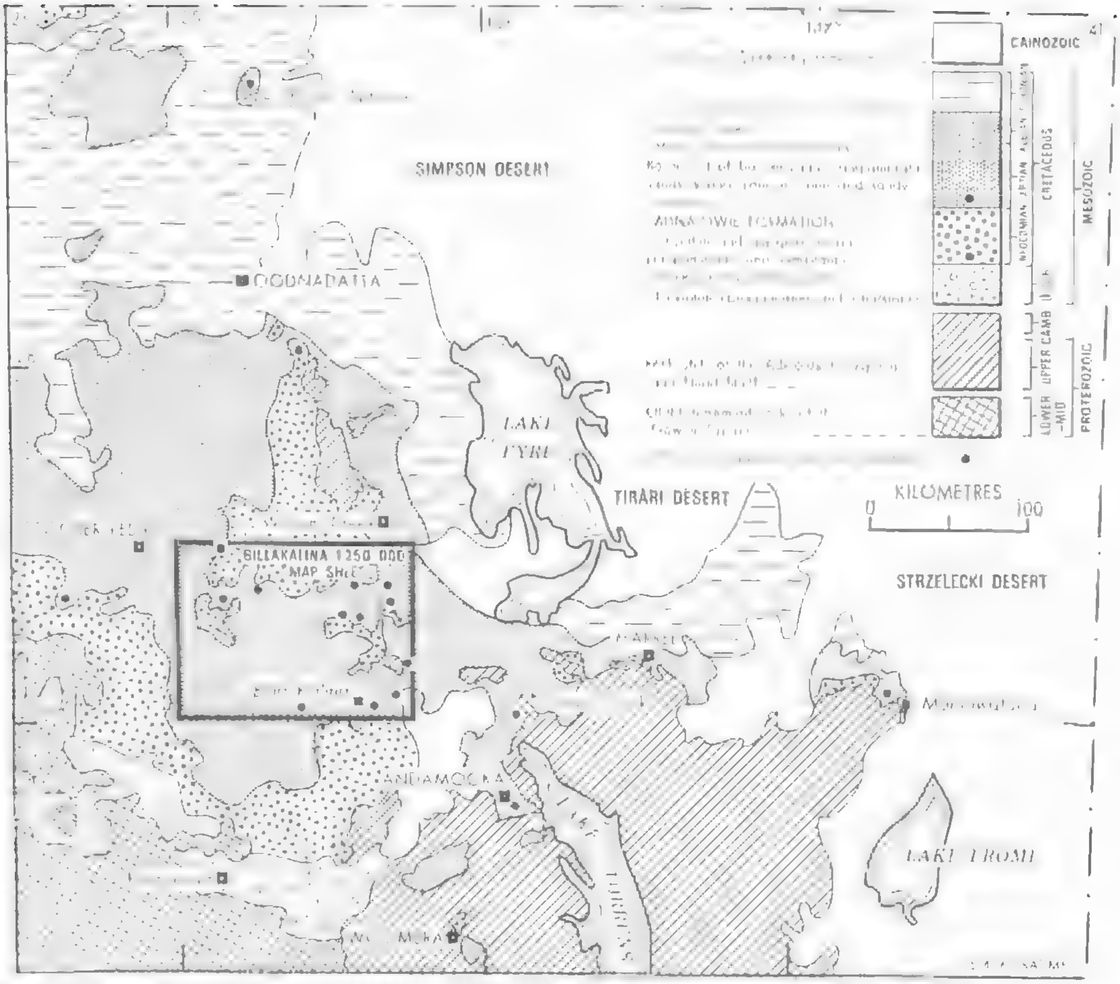


Fig. 1. Geological map of southwestern margin of Great Australian Basin, modified from Thomson (1980). All known localities of fossiliferous Devonian quartzite boulders in S.A. shown.

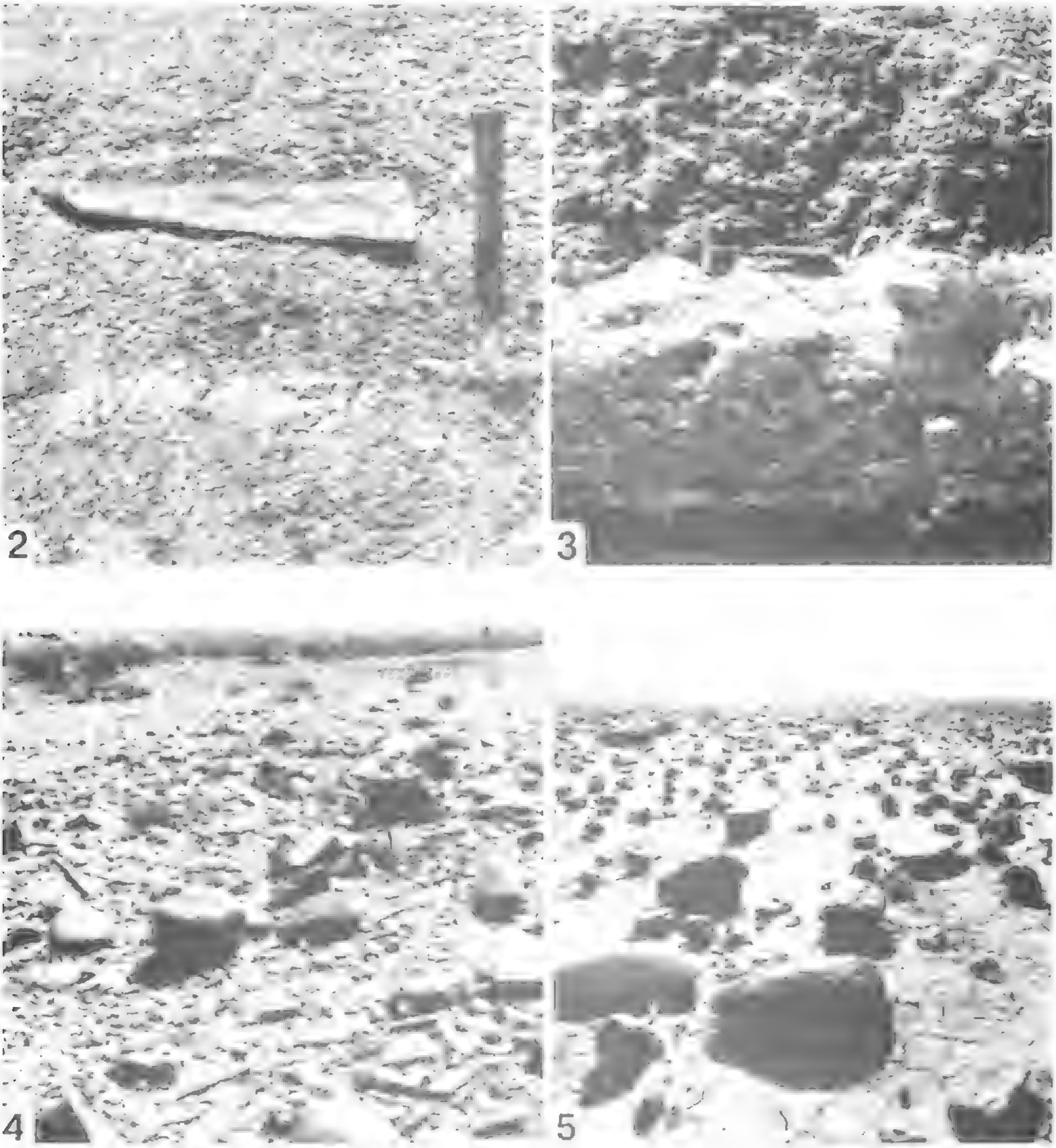
rounded to well-rounded white quartz pebbles. However, weathered acid porphyry and quartzite pebbles and cobbles are also common. The unit was deposited in a low gradient, fluviatile environment.

Transgression in the Neocomian led to the disconformably overlying Cadna-owie Formation, consisting of marginal marine very fine to medium-grained, micaceous and occasionally conglomeratic sandstones. Clasts within the sandstones are chiefly pebble, cobble and boulder-sized quartzites up to 1 x 1 x 0.5 m. Later in the Neocomian, partial regression led to the deposition of the coarser Mount Anna Sandstone which consists of medium to coarse-grained, feldspathic and conglomeratic sandstones and micaceous sandstones. Clasts of porphyritic acid volcanics characterise the conglomeratic sandstones, though white quartz and quartzite clasts are also common. The clasts are sub-rounded to well-rounded and in the size range 0.02-0.2 m. Concave and festoon cross bedding are ubiquitous; foresets are up to 2 m high and bedding within the foresets is graded.

The second Cretaceous marine transgression, in Aptian time, was of much greater extent and resulted in marine shale deposition (Bulldog Shale) over a large area of the Great Australian Basin. Basal lithologies of the Bulldog Shale range from bouldery to conglomeratic sand to grey shales, cone-in-cone limestones and sandy limestone. Fossil tree trunks are common. Clasts within the conglomeratic sediment are predominantly quartzites with minor acid porphyries and banded chalcedony, and

occur in either bioturbated grey shales or thin coarse-grained sand lenses (Fig. 2). The sand lenses vary from only a few centimetres thick to massive lenses up to a metre thick with boulders scattered in the sandy matrix (Fig. 3). These sediments interfinger with and are overlain by bioturbated dark grey shales and silts, and fossiliferous limestones. A subsequent regression and a further two transgressive-regressive cycles occurred in the Albian to Turonian.

The fossiliferous Devonian quartzite boulder from the locality southeast of Oodnadatta is the only specimen weathered out from mar-



Figs 2-5. 2, Unfossiliferous quartzite boulder within bioturbated marine shales of Cretaceous Bulldog Shale, 60 km north of "Billa Kalina"; 3, Rounded quartzite cobbles near top of coarse-grained sand lens, and overlying bioturbated marine shales (Bulldog Shale) from 20 km east of Billa Kalina locality 1; 4, Well-rounded quartzite boulder lag near Billa Kalina locality 2. Many boulders are fractured due to Holocene weathering; 5, Surface gibber lag east of Coober Pedy: cobbles and boulders derived from basal sediments of Bulldog Shale. Clasts are dominantly quartzites; less than 1% contain Devonian fossils.

ginal marine sediments of the Cadna-owie Formation. All other fossiliferous boulders (including the original two specimens discovered at Dalhousie Springs and Andamooka, and previously thought to be derived from the Cadna-owie Formation) have weathered out from basal conglomeratic sediments of the Bulldog Shale.

Description of the boulders

Basal conglomeratic sediments of the Bulldog Shale crop out poorly but erosion has resulted in numerous clasts from the conglomerates, ranging in size from pebbles to boulders, forming a lag on the present day land surface (Figs 4, 5). Physically-resistant clast types dominate, mostly quartzites (feldspathic and/or lithic), with minor porphyritic acid volcanics and whitish-grey banded chalcedony. Granite, gneiss, quartz and shale clasts are rare, but may be locally more common near Proterozoic outcrops.

A high proportion of the quartzite boulders have abundant clay pellet impressions, a feature typical of the Upper Proterozoic Arcoona Quartzite on the Stuart Shelf. The porphyritic acid volcanics are similar to the Middle Proterozoic Gawler Range Volcanics on the Gawler Craton (Wopfner *et al.* 1970), while banded chalcedony clasts are similar to cherts and siliceous concretions in the Cambrian Andamooka Limestone.

Less than 1% of all boulders contain Devonian fossils. The fossiliferous boulders are siliceous, feldspathic and lithic quartzites. They consist of quartz-rich, medium-grained sand (0.2-0.3 mm) and minor (<10%) potash feldspar grains cemented by secondary quartz overgrowths. The lithic quartzites contain small fragments of sericitic schists and acid porphyries (Whitehead 1978)[3]. It is not possible to distinguish lithologically between fossiliferous Devonian quartzites and other quartzite clasts.

Faunas of the boulders

In the two fossiliferous Devonian boulders previously recorded in South Australia (Campbell *et al.* 1977), the specimen from Dalhousie Springs contained the brachiopod *Howellella jaqueti* (Dun) and bivalve *Actinopteria* sp.; these were also present in the specimen collected from Andamooka. In the latter sample tentaculitids and brachiopod *Isorthis* sp. were also present. The fossils found in the boulders during 1977-78 are documented below, and include many species not recorded previously in the boulders. All specimen numbers refer to the fossil collection of the Geological Survey of South Australia.

Billa Kalina locality 1 (lat. 29°28'10"S, long. 136°08'00"E) — Specimen numbers 6139 RS 29-34, 39.
- Fish plate: *Wuttagoonaspis* sp. (Fig. 6)
- Brachiopods: *Howellella jaqueti* (Dun)
  - Brachiopoda indet.
- Bivalves: *Leptodesma inflatum* (Dun)
  - Bivalvia indet.
- Tentaculitid: *Tentaculites* sp. (Fig. 7)

Billa Kalina locality 2 (lat. 29°28'00"S, long. 136°06'50"E) — Specimen numbers 6139 RS 35-36.
- Brachiopod: *Howellella jaqueti* (Dun)

Billa Kalina locality 3 (lat. 29°58'20"S, long. 136°12'50"E) — Specimen numbers 6138 RS 74-77
  - Brachiopoda indet.
  - Bivalvia indet.
  - Fish plates and spines

Billa Kalina locality 4 (lat. 29°57'30"S, long. 136°18'35"E) — Specimen numbers 6138 RS 78-85.
- Brachiopods: *Howellella jaqueti* (Dun)
  - Brachiopoda indet.
- Bivalves: *Sanguinolites* sp.
  - Bivalvia indet.
- Gastropods: *Straparollus culleni* (Dun) (Fig. 8)
  - *Holopea* sp.
  - Murchisoniidae indet.
- Echinodermata indet.
- Fish Plates and spines

Billa Kalina locality 5 (lat. 29°11'00"S, long. 136°21'05"E) — Specimen number 6139 RS 37
- Tentaculitid: *Tentaculites* sp.
- Crinoid ossicles
- Bryozoa indet.

Billa Kalina locality 6 (lat. 29°12'15"S, long. 136°09'05"E) — Specimen number 6139 RS 38.
- Bivalve: Bivalve indet.
- Crinoid ossicles

Billa Kalina locality 7 (lat. 29°02'05"S, long. 135°12'20"E) — Specimen number 5939 RS 92.
- Brachiopod: Brachiopoda indet.
- Crinoid ossicles

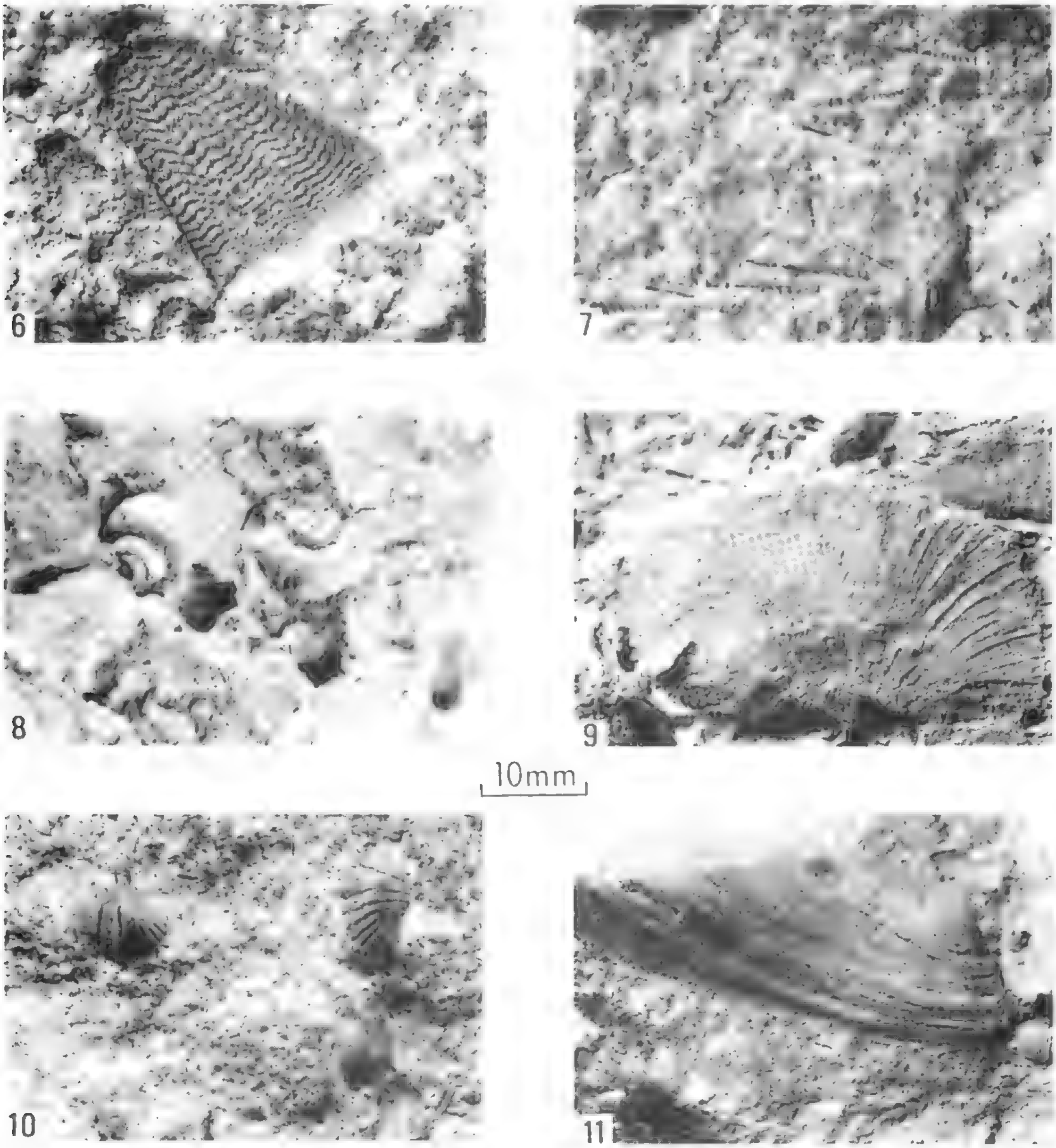
Billa Kalina locality 8 (lat. 29°55'00"S, long. 135°49'30"E) — Specimen numbers 6038 RS 12-13.
- Brachiopods: Stropheodontid (probably *Mesodouvillina* or *Mclearnites*) (Fig. 9)
  - Brachiopoda indet.

[3] Whitehead, S. (1978) Description of quartzite boulders. Amdel Rept. No. GS 415/79 (unpublished).

Tentaculitid: *Tentaculites* sp.
Crinoid fragments
Bryozoa indet.

Moolawatana (lat. 20°52′12″S, long. 139°38′00″E) — Specimen numbers 6838 RS 129-132.

Brachiopods: *Howellella jaqueti* (Dun) (Fig. 10)
Brachiopoda indet.
Bivalves: *Leptodesma inflatum* (Dun)
Bivalvia indet.
Tentaculitid: *Tentaculites* sp.



Figs 6-11. 6, External impression of unidentified plate of *Wuttagoonaspis*, specimen 6139 RS 39 from Billa Kalina locality 1; 7, Numerous aligned external moulds of *Tentaculites* sp., specimen 6139 RS 32 from Billa Kalina locality 1; 8, Two internal moulds *Straparollus culleni* (Dun), sample 6138 RS 79 from Billa Kalina locality 4; 9, External mould of pedicle valve of stropheodontid brachiopod (*Mesodouvillina* or *Mclearnites*), sample 6038 RS 12 from Billa Kalina locality 8; 10, Internal moulds of pedicle and brachial valve of *Howellella jaqueti* (Dun), specimen 6838 RS 129 from "Moolawatana" locality; 11, External mould of *Sanguinolites* sp. from Stuarts Creek locality, specimen 6337 RS 21.

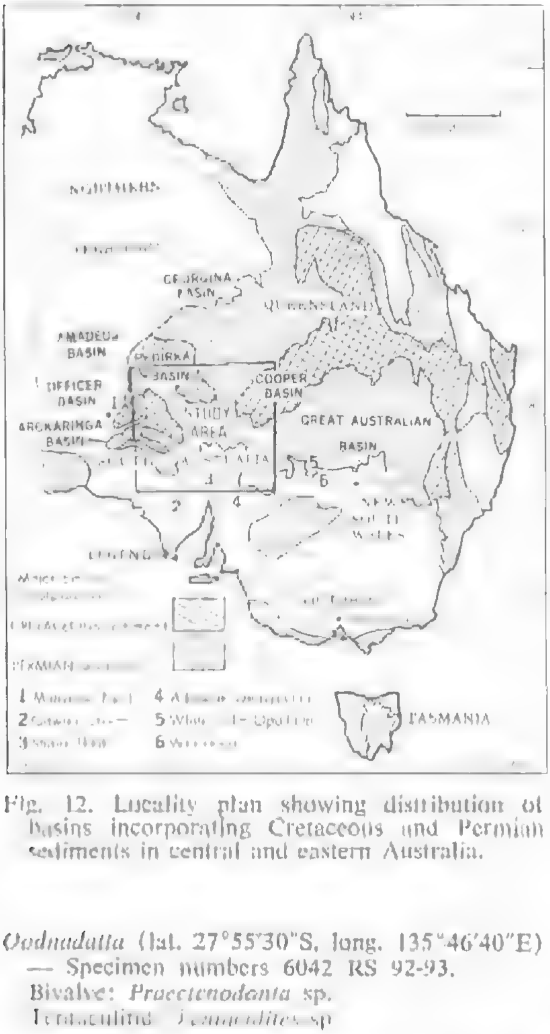


Fig. 12. Locality plan showing distribution of basins incorporating Cretaceous and Permian sediments in central and eastern Australia.

Oodnadatta (lat. 27°55'30"S, long. 135°46'40"E) — Specimen numbers 6042 RS 92-93.
Bivalve: *Praectenodonta* sp.
Tentaculitid: *Tentaculites* sp.

Stuarts Creek (lat. 30°03'45"S, long. 137°11'30"E) — Specimen numbers 6337 RS 21-34.
Brachiopods: *Sphaerirhynchia* sp.
Howellella jaqueti (Dun)
Bivalves: *Sanguinolites* sp. (Fig. 11)
Tentaculitid: *Tentaculites* sp.
Crinoid ossicles.

Provenance of the fossiliferous boulders

Neither the invertebrate nor the vertebrate faunas preserved in the boulders have been recorded from *in situ* Devonian sediments in basins in S.A., or the adjacent Amadeus or Georgina Basins. The only possible Devonian vertebrates known from S.A. are the fish scales from a mudstone at 817–823 m in Munyarai No. 1 within the Officer Basin (Fig. 12), but these were not positively identifiable (Gilbert-Tomlinson 1969)[1]. Devonian placoderm remains from the Amadeus and Georgina Basins are bothriolepids (Young 1974) which are not similar to the specimens from the boulders. No Devonian invertebrates are known from the above basins. However, as has been indicated previously, both the lithologies and invertebrate faunas are very similar to those from the Amphitheatre Group near Cobar in N.S.W., described by Landrum (1975), and to those from the boulders in Cretaceous sediments at White Cliffs, N.S.W., described by Dun (1898).

On the other hand, marine Lower Devonian sandstones with comparable invertebrate faunas to those at Cobar are also known from the Mt Ida Formation of central Victoria and the Eldon Group of western Tasmania. These have to be considered as alternative source areas, but there are good reasons for rejecting them. The absence of *Notoconchidium* from the boulders in S.A. is taken as evidence against either a Victorian or a Tasmanian source because this genus is relatively common in a hard quartzite in both these areas. The durability of this material is attested by the fact that *Notoconchidium* is among the more common fossils in the Lower Devonian boulders from Permian diamictites in north-eastern Victoria. A second important feature is the abundance of *Howellella jaqueti* in boulders from S.A. Although *Howellella* occurs in a variety of forms at Heathcote, Talent (1965) records that they are poorly preserved. The genus is also poorly represented in the Eldon Group. *H. jaqueti* is one of the most common species in boulders from S.A., as it is in several horizons in the Amphitheatre Group.

Although there are now many more boulders with a wider range of species than was known previously, it still is possible to match the entire invertebrate fauna with that from the Amphitheatre Group. In the absence of a complete account of the Eldon Group fauna, this evidence of itself can be no more than suggestive; but taken in conjunction with the data on *Notoconchidium* and *Howellella* given above it is more persuasive of a Cobar source.

[1] Gilbert-Tomlinson, J. (1969) Fossils from Munyarai No. 1 Well, Officer Basin, South Australia. *In* "Continental Oil Company of Australia Ltd. Munyarai No. 1, South Australia." Well completion report. S. Aust. Dept Mines & Energy env. 979 (unpublished).

Further weight is lent to this view by the discovery of fossil fish fragments in boulders at three of the Billa Kalina localities. So far as we are aware no Devonian fish beds are known from Tasmania, though they are well exposed in central and eastern Victoria and over much of central N.S.W., where they are mainly of Late Devonian age. The most important discovery is the fragment referred to *Wuttagoonaspis* Ritchie (1973) from the Mulga Downs Formation of probable Middle Devonian age in the Mt Grenfell area west of Cobar, and Mt Jack north of Wilcannia. This specimen is only an impression of a fragment of an undetermined bone, but its ornamentation is distinctive. Its identification has been confirmed by Ritchie.

We therefore conclude from the available evidence that the source for the fossiliferous boulders is in the Cobar region, the boulders having been transported at least 1000 km in a westerly to northwesterly direction.

Transport of the boulders

A palaeoenvironmental interpretation of Jurassic-Cretaceous sediments in the southwestern Great Australian Basin by Wopfner *et al.* (1970) indicates that transport of boulders in this direction and for this distance during the Mesozoic was improbable. However, Permian ice may have transported the fossiliferous boulders from the Cobar area to northern S.A., and the unconsolidated Permian diamictites could then have been reworked into Mesozoic sediments (Campbell *et al.* 1977). Thus two phases of transport would be involved.

In northern S.A., Permian diamictites are preserved in Palaeozoic basins under the Great Australian Basin (e.g. Arckaringa, Cooper and Pedirka Basins) and in small grabens within the Gawler Block. These distributions suggest that such deposits were once widespread but that they have been largely removed from uplifted areas.

Crowell & Frakes (1975) using the distribution of glacial till and fluvial sediments and palaeocurrent analysis, postulated a large Permian continental ice cap over northwestern N.S.W., with glacial debris being shed eastwards and possibly westwards into the basins of northeastern S.A. This interpretation differs from that of Wopfner (1970) who concluded that the composition of erratics in Permian diamictites of the Arckaringa Basin indicated local glaciation rather than a continental ice sheet. He suggested that Permian glaciers originated on upfaulted highland areas; glacial debris was dumped along basin margins and then transported by mudflows and turbidity currents into distal parts of the basins.

Though we prefer the views proposed by Crowell & Frakes, it must be stressed that to date no fossiliferous Devonian boulders have been discovered in Permian diamictites in S.A., ice-movement directions during the Permian are not known for northern S.A., and there are conflicting views on the Permian palaeoenvironment and likelihood of long-distance transport. Nevertheless, ice transport seems to be the only feasible means for transporting boulders from the Cobar area to northern S.A., and the Permian is the only period in the required interval for which glaciation of an appropriate magnitude has been demonstrated.

Final emplacement of the boulders

The processes by which the Cretaceous boulder beds were formed have been debated for nearly 100 years. This paper is not intended to provide a detailed discussion of the problem, but it does add another feature that requires explanation — viz. the distant provenance of some of the boulders. It has been thought appropriate that a summary of the issues should be presented.

Features requiring explanation are

(a) the scatter of boulders through a sandy or shaly matrix which is bioturbated in places;

(b) the rounded form of most of the boulders, though an occasional facetted or striated boulder has been noted (Jack 1915; Woolnough & David 1926);

(c) the predominance of quartzites among the boulders, with acid porphyries and chalcedony forming the majority of the remainder;

(d) the occurrence of fossiliferous boulders in Cretaceous rocks from White Cliffs to Dalhousie Springs.

The shape and composition of the boulders indicates the operation of processes that have removed all but the most durable materials, and that these processes were at least in part physical. Tumbling experiments by Abbott & Peterson (1978) showed chert, quartzite and rhyolite to be the most durable rock types, followed by metabreccia, obsidian, metasandstone, gneiss, 'granites', metabasalt, marble and schist. The first three rocks are also chemically resistant.

One possible source for many of the clasts is in Proterozoic/Cambrian rocks such as those of the Gawler Craton and Broken Hill Block which could provide abundant quartzite, acid porphyry (Gawler Range Volcanics) and chalcedony (Andamooka Limestone). A second source would be the Permian diamictite, mentioned above, which is known to contain clasts of limestone, schist, gneiss, granite, acid porphyry, quartzite, quartz, banded iron formation, chert and shale. The original source of many of these clasts must have been the Proterozoic/Cambrian rocks indicated above. Both the above sources would have been subjected to prolonged weathering between the Permian and the Early Cretaceous, and transport to the Cretaceous sea with subsequent shoreline deposition would have resulted in the removal of the less durable clasts.

Brown (1905), Jack (1915), Woolnough & David (1926) and Vnuk[2] considered that ice rafting was responsible for the final transport of the boulders and that they were mainly dropstones. In our view this mechanism is not acceptable. If the proposed ice was calved off from glaciers there would be no explanation for the dominance of resistant clasts, their rounded shapes, or their abundance over so large a geographical distribution. If sea ice picking up clasts from a boulder-strewn shore were proposed, it would be possible to explain the clast types and shapes, but the problems of volume and distribution would remain. In addition there is no independent evidence of glacial conditions in the Early Cretaceous, though the area in question would have been within 30° of the pole.

Woolnough & David (1926) also considered, but rejected, tree rafting as a possible transport mechanism for the boulders. Much later Wopfner *et al.* (1970) reinstated the proposal because of the abundance of fossil wood in Early Cretaceous sediments. However because of the abundance and concentration of boulders within particular horizons, tree rafting was not accepted as the sole transport mechanism. Since they considered the boulder beds to be restricted to margins of basement highs, they also proposed that the boulders originated on shorelines and migrated downslope by slow sediment creep. It is this latter suggestion that seems to us to provide a clue to a possible solution — namely that they are reworked debris-flow deposits. Bouldery debris-flow deposits typically consist of a massive fine-grained matrix with randomly dispersed boulders (Fisher 1971; Middleton & Hampton 1973; Carter 1975; Hampton 1975) but the beds under discussion are not of this type. Some other processes must have been operative in addition. We propose, therefore, that boulders, cobbles and sand were transported basinwards from a boulder-strewn shore line in a clay-rich, watery matrix over low angle slopes. The debris flows were episodic events, permitting time for some reworking of the debris-flow sediments, and subsequent shale sedimentation and bioturbation. Winnowing of muds and fine sands from the debris-flow sediments by currents, and possibly by waves, has resulted in some of the boulders and cobbles being concentrated in thin, coarse-grained sand lenses. Complete winnowing of the fines and further shale deposition has resulted in some boulders being located within bioturbated shales.

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PROGAMOTAENIA NYBELIN (CESTODA: ANOPLOCEPHALIDAE): NEW SPECIES, REDESCRIPTIONS AND NEW HOST RECORDS

BY I. BEVERIDGE

Summary

The following species are described: Progamotaenia spearei sp. nov., from Thylogale stigmatica, distinguished by its small size, in having paired uteri, a fringed veleum and testes in two groups, and Progamotaenia johnsoni sp. nov. from Lagorchestis conspicillatus, which has an external seminal vesicle covered with glandular cells and testes distributed in two elongate groups. P. bancrofti (Johnston) and P. diaphana (Zschokke) are redescribed, and Lasiorhinus latifrons is considered to be the usual host of the latter species. P. zschokkei (Janicki) is reported for the first time from Macropus agilus, Onychogalea fraenata and O. unguifera; additional records of this species from Petrogale penicillata, Lagorchestes conspicillatus and Thylogale stigmatica are given.

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Summary

BEVERIDGE, I. (1980) *Progamotaenia* Nybelin (Cestoda: Anoplocephalidae): new species, redescriptions and new host records. *Trans. R. Soc. S. Aust.* 104(4), 67-79, 30 May 1980.

The following species are described: *Progamotaenia spearei* sp. nov., from *Thylogale stigmatica*, distinguished by its small size, in having paired uteri, a fringed velum and testes in two groups, and *Progamotaenia johnsoni* sp. nov. from *Lagorchestis conspicillatus*, which has an external seminal vesicle covered with glandular cells and testes distributed in two elongate groups. *P. bancrofti* (Johnston) and *P. diaphana* (Zschokke) are redescribed, and *Lasiorhinus latifrons* is considered to be the usual host of the latter species. *P. zschokkei* (Janicki) is reported for the first time from *Macropus agilis*, *Onychogalea fraenata* and *O. unguifera*; additional records of this species from *Petrogale penicillata*, *Lagorchestes conspicillatus* and *Thylogale stigmatica* are given.

Introduction

Although the anoplocephalid cestodes of Australian marsupials have been the subject of a recent review (Beveridge 1976), continued collecting has resulted in the discovery of additional new species of *Progamotaenia* (Beveridge 1978, Beveridge & Thompson 1979). To date most collections have been from marsupial species inhabiting the south-eastern part of the continent. Recent collecting from macropodids in north Queensland has led to the discovery of two new species of *Progamotaenia*.

Progamotaenia bancrofti and *P. diaphana*, were recently redescribed by Beveridge (1976) on the basis of very limited or poorly preserved material only. Both are well represented in recent collections, and the opportunity is taken here to describe them fully.

Materials and methods

Cestodes collected from the small intestines of macropodids were washed in tap water, relaxed in water for several hours and fixed in 10% formalin or Serra's fluid. They were stained with Celestine blue, cleared in methyl salicylate or clove oil and mounted in balsam. Hand cut transverse sections and serial histological sections cut in transverse and longitudinal planes were prepared. Drawings were made with the aid of a camera lucida. Measurements are given in mm as the range followed by the mean of five measurements (where available) in parenthesis.

Type specimens have been deposited in the South Australian Museum (SAM).

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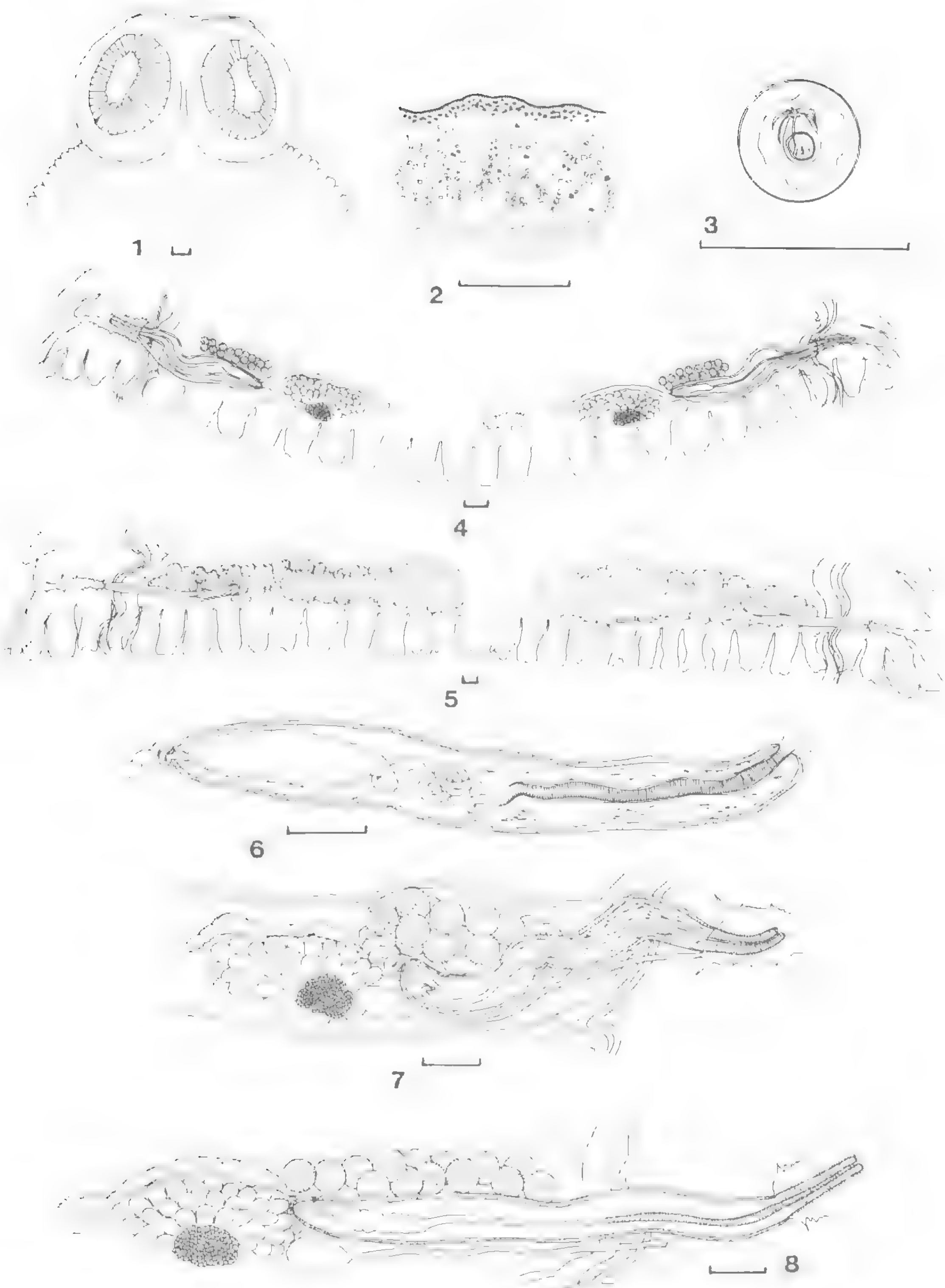
Progamotaenia spearei sp. nov.

FIGS 1–8

Types: holotype (slide) from small intestine of *Thylogale stigmatica* Gould 1860, Tolga Queensland, 16 .x. 1978, collected by I. Beveridge, in SAM V1920: 4 paratype slides, same data V1921–V1924; 1 paratype, spirit material and serial sections V1925, V1926.

Description: Length 26–30 (28); width 5–7 (6); scolex diameter 1.31–1.52 (1.44); sucker diameter 0.56–0.74 (0.67) x 0.47–0.58 (0.55); neck 0–0.21 (0.09); no. proglottides 71–85 (78); mature proglottides 3.8–4.0 (3.9) x 0.21–0.28 (0.23); gravid proglottides 4.1–5.8 (5.4) x 0.56–0.74 (0.65); cirrus sac in mature proglottides 0.60–0.92 (0.81) x 0.08–0.12 (0.10); cirrus sac in gravid proglottides 0.93–0.98 (0.94) x 0.11–0.14 (0.12); no. testes per proglottis 30–40 (34); testis diameter 0.06–0.09 (0.08); ovary 0.50–0.56 (0.53) x 0.18–0.21 (0.20); vitellarium 0.11–0.18 (0.15) x 0.08–0.12 (0.10); dorsal osmoregulatory canal 0.02–0.03 (0.02); ventral osmoregulatory canal 0.03–0.09 (0.07); egg 0.06–0.08 (0.07); pyriform apparatus 0.03-0.04 (0.04); oncosphere 0.02.

Short broad tapeworms with relatively few proglottides. Scolex squat, almost globose, prominently four-lobed, each lobe with muscular, cup shaped sucker. Neck absent or, if present, very short, segmentation beginning very close to suckers. Proglottides extended transversely, craspedote with broad, fringed velum consisting of about 25–35 tongue shaped projections which are frequently folded and overhand 1/2–2/3 of the adjacent proglottis. Mature proglottides with approximate length:



Figs 1-8. *Progamotaenia spearei* sp. nov. 1. scolex; 2. transverse histological section through cortex showing musculature; 3. egg; 4. mature proglottis; 5. gravid proglottis; 6. cirrus sac; 7. lateral region of mature proglottis prior to vaginal atrophy and uterine filling; 8. lateral region of mature proglottis at commencement of uterine filling, showing atrophy of vagina. Scale lines 0.1 mm.

width ratio of 1:14 to 1:20. Gravid proglottides with ratio 1:6 to 1:10. Cortex thick. Longitudinal muscles developed, numerous, not arranged in regular bundles, denser towards cortico-medullary junction. Transverse muscles well developed, forming thick band running along cortico-medullary junction. Dorso-ventral muscles prominent, crossing cortex and medulla at irregular intervals. Longitudinal osmoregulatory canals paired. Ventral canal wider than dorsal canal, situated medial to it. Two transverse canals connect left and right osmoregulatory canals at posterior margin of each proglottis. Canal connecting ventral vessels of moderate size, readily observed; canal connecting dorsal canals extremely fine, seen only with difficulty. Fine accessory canals associated with ventral canal in some proglottides; accessory canals branch and anastomose irregularly. Junction of osmoregulatory canals in scolex not seen. Genital ducts cross osmoregulatory canals dorsally. Genital atrium prominent, very long; walls lined with thickened tegument, opening in middle of lateral proglottis margin. Cirrus sac elongate, musculature of walls strongly developed, crossing beyond osmoregulatory canals, reaching almost to ovary. Cirrus narrow, distal third covered with numerous prominent spines; mid. third unarmed, greatly coiled when retracted, uncoiled when cirrus is everted. Internal seminal vesicle prominent, elongate. External seminal vesicle absent. Vas deferens coils anteriorly and medially from cirrus sac. Vasa efferentia not seen. Testes distributed in two compact clusters anterior to cirrus sac, extending medially from osmoregulatory canals to poral side of ovary; never extending medially beyond ovary to form single band. Vagina tube-like, opening to genital atrium posterior to cirrus sac. Vagina leads medially to diminutive, ovoid, seminal receptacle situated posterior to median pole of cirrus sac, lateral to ovary. Ovary fan-shaped, composed of numerous clavate lobules, on ventral aspect of medulla. Vitellarium ovoid, situated posterior and dorsal to ovary. Mehlis' gland spherical, medial to vitellarium. Uterus transverse, tube-like, paired in each proglottis, anterior to ovary. Fully developed uterus sacciform with prominent anterior diverticula; posterior diverticula very small. Uteri fill space between osmoregulatory canals but do not extend beyond canals except in last few gravid proglottides; uteri cross canals dorsally but do not reach posterolateral corners of proglottis. Egg spherical, thick-shelled. Pyriform apparatus conical, terminating in reflexed filaments. Genital primordia appear in 6–10th proglottis; genital organs are developed by 15–18th proglottis; sperm present in internal seminal vesicle in 15–20th proglottis; filling of seminal receptacle and atrophy of vagina occur in 16–24th proglottis; uterus begins to fill in 22–26th proglottis; eggs fully formed in 69–73rd proglottis.

Vestigial supernumerary vitellaria, ovaries or uterine fragments present in proglottides of some strobilae, of variable size, arranged between two normal sets of genital organs.

Discussion: Progamotaenia spearei most closely resembles *P. proterogyna* (Fuhrmann 1932) in external features, being a small worm, with few proglottides and with a fringed velum. It differs in the shape of fringes of the velum, the occurrence of testes in two distinct groups rather than in a continuous band and in the occurrence of vaginal atrophy following insemination. *P. gynandrolinearis* Beveridge & Thompson 1979 is another small species, but the velum is not fringed. *P. spearei* resembles *P. lagorchestis* (Lewis 1914) and *P. thylogale* Beveridge & Thompson 1979 in having a fringed velum, paired uteri and testes occurring in two lateral groups, but differs from both species in its small size, small number of proglottides, the rapidity of development of the genital organs in the strobila and the small number of testes.

This species is named after Dr R. Speare, James Cook University of North Queensland, in appreciation of help given in collecting material.

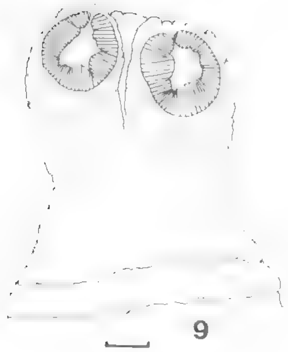
Progamotaenia johnsoni sp. nov.

FIGS 9–15

Types: holotype (without scolex) from small intestine of *Lagorchestes conspicillatus* Gould, 1842, Mingela, Queensland, 10.v.1979, collected by I. Beveridge, 6 slides, spirit material and serial section in SAM V1918; paratype slide, same data, V1919.

Material examined: from *Lagorchestes conspicillatus*: types; 4 specimens (non gravid), Inkerman Station, Qld, 7.ix.1977, P. M. Johnson.

Description: Length 178 (holotype); width 13 (holotype); scolex diameter 0.74–1.21 (0.86); sucker diameter 0.30–0.42 (0.32) x 0.28–0.36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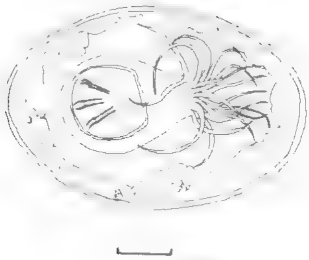
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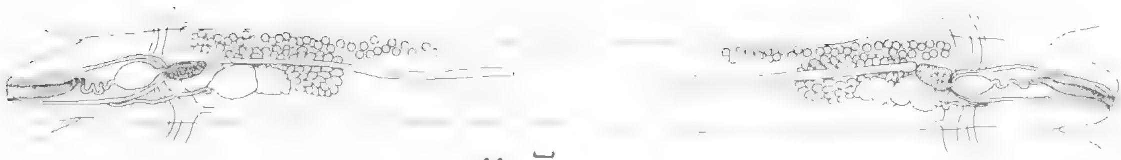
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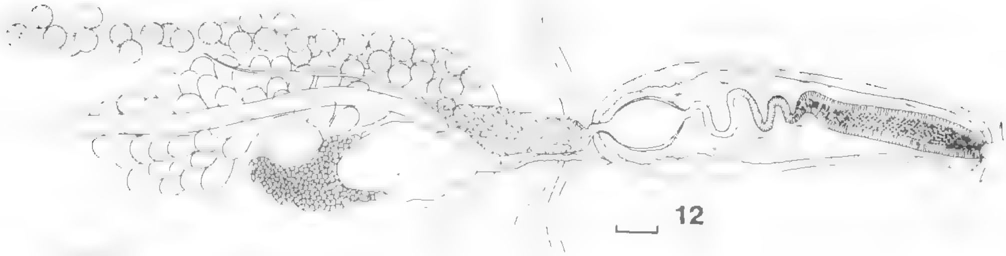
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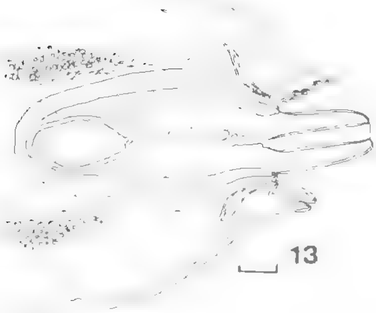
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(0.31); neck 0.16–0.36 (0.26); no. proglottides 272 (holotype); mature proglottides 5.4–7.0 (6.2) x 0.52–0.56 (0.54); gravid proglottides 9.4–9.8 (9.6) x 0.92–0.99 (0.96); cirrus sac in mature proglottides 0.46–1.31 (0.90) x 0.16–0.29 (0.25); in gravid proglottides 1.08–1.18 (1.14) x 0.34–0.36 (0.35); no. testes per proglottis 100–190 (178); testis diameter 0.05–0.08 (0.06), ovary 0.62–0.80 (0.72) x 0.34–0.38 (0.36); vitellarium 0.30–0.40 (0.37) x 0.17–0.23 (0.18); Mehlis' gland 0.10–0.14 (0.12); dorsal osmoregulatory canal 0.02–0.04 (0.03); ventral osmoregulatory canal 0.08–0.29 (0.18); egg 0.064–0.072 (0.068); pyriform apparatus 0.024–0.28 (0.025); oncosphere 0.009–0.016 (0.015).

Large, broad, ribbon-like worms. Scolex broad, four-lobed, with cup-shaped sucker at apex of each lobe. Suckers with anterior margins cleft. Neck short. Proglottides greatly extended transversely, craspedote, with broad, fleshy, folded velum covering much of adjacent proglottis. Mature proglottides with approximate length:width ratio of 1:10 to 1:13. Gravid proglottides with ratio of 1:9 to 1:11. Longitudinal musculature powerfully developed, composed of pallisades of muscle bundles. Bundles circular or oval in section; outer bundles smaller, with fewer fibres. Outer longitudinal musculature consists of ring of individual fibres, immediately external to muscle bundles. Transverse muscles well developed, forming broad band immediately internal to longitudinal muscle bundles. Few, scattered transverse muscle fibres present in outer cortex. Towards lateral margins of proglottides, transverse muscles from cortex and cortico-medullary junction fuse into thick band of muscle encircling cirrus sac and extending to genital atrium. Dorso-ventral muscle fibres well developed, prominent, crossing cortex and medulla at regular intervals. Longitudinal osmoregulatory canals paired. Ventral canal wider than dorsal canal, situated medial to it. Transverse canal connects left and right ventral canals at posterior margin of each proglottis. Scolex osmoregulatory canals not seen. Genital ducts cross osmoregulatory canals dorsally. Genital atrium shallow, with corrugated walls, opening in middle of lateral proglottis margin. Cirrus sac powerfully developed, with thick muscular walls, extending to medial margin of, or beyond longitudinal osmoregulatory canals into medulla. Cirrus wide at distal extremity, heavily armed with spines; mid-region of narrower diameter, distal part armed, proximal part unarmed. Internal seminal vesicle ovoid, with thick, muscular walls. External seminal vesicle large, elongate, sometimes coiled, covered externally with layers of glandular cells. Vas deferens leads medially from external seminal vesicle, gradually diminishing in diameter. Vasa efferentia not seen. Testes in two lateral groups anterior to female genitalia, each group extending from osmoregulatory canals medially beyond medial border of ovary, occasionally almost to middle of proglottis. Testes in 2–4 longitudinal and 1–3 transverse rows. Vagina tube-like, narrow, opening to genital atrium posterior to cirrus sac. Vagina leads medially, along posterior border of cirrus sac to ovoid seminal receptacle situated lateral to vitellarium. Ovary fan-shaped, composed of numerous clavate lobules, on ventral aspect of medulla. Vitellarium ovoid to reniform, dorsal and posterior to ovary. Mehlis' gland spherical, anterior to vitellarium. Uterus transverse, tube-like, paired in each proglottis, dorsal to ovary. Tubular uterus extends from near centre of proglottis, dorsal to ovary, anterior to vitellarium, terminating between proximal pole of external seminal vesicle and seminal receptacle. Fully developed uterus sacciform, with prominent anterior and posterior diverticula. Uteri cross longitudinal osmoregulatory canals dorsally, extending to postero-lateral corners of proglottis. Egg ellipsoidal, thick shelled. Pyriform apparatus conical, terminating in reflexed filaments. Genital primordia appear in c.20th proglottis; cirrus sac developed by 26–30th proglottis; internal seminal vesicle fills with sperm in 33–47th proglottis; insemination occurs in 40–46th proglottis; vaginal atrophy not seen; full maturity of female genitalia reached in c.50th proglottis.

Discussion: Although described from a limited amount of material, *Progamotaenia johnsoni* is sufficiently distinctive to be readily recognised. The gravid holotype is, unfortunately,

Figs 9-15. *Progamotaenia johnsoni* sp. nov. 9. scolex; 10. egg. 11. mature proglottis; 12. lateral region of mature proglottis showing genitalia; 13. transverse histological section through lateral region of mature proglottis showing cirrus sac and musculature, 14. transverse histological section through cortex showing musculature, 15. gravid proglottis. Scale lines, fig. 10, 0.01 mm. figs 9, 11-15, 0.1 mm.

without scolex, but the remaining specimens are not gravid. Mature proglottides of the specimens from Inkerman are identical morphologically with those of the holotype, and there is no doubt that they are conspecific. There is no possibility of confusion with congeners that occur in *L. conspicillatus*, reviewed by Beveridge & Thompson (1979), since other intestinal species occurring in this host in eastern Australia have markedly fimbriated vela (Beveridge 1976).

P. johnsoni most closely resembles *P. bancrofti* in being a very large, thick species with greatly extended proglottides, a broad unfringed velum, a powerfully developed cirrus sac and armed cirrus and an external seminal vesicle covered with glandular cells. The last characteristic distinguishes *P. johnsoni* and *P. bancrofti* from all congeners. *P. johnsoni* is distinguished from *P. bancrofti* by a smaller scolex, a muscular wall to the internal seminal receptacle, the presence of a pyriform apparatus in the egg, and most importantly of all, in the distribution of the testes, which in *P. johnsoni* extend from the osmoregulatory canals beyond the medial margin of the ovary almost to the centre of the proglottis, but which are restricted in *P. bancrofti* to the region lateral to the ovary. Although in every proglottis of *P. johnsoni* examined, the testes were distributed in two groups, in some cases, the distance between the two groups of testes in the centre of the proglottis was quite small and examination of further specimens may well reveal instances in which the two groups of testes fuse in the midline.

An unusual feature of the anatomy of *P. johnsoni* is the condensation of muscle fibres to form a sphincter-like annulus around the distal extremity of the cirrus sac. A sphincter surrounding the genital atrium has been described in a number of species of *Progamotaenia* (Baer 1927, Lewis 1914), but Beveridge (1976) considered that the structures reported by the earlier writers in no way constituted a sphincter, consisting as they did of an accumulation of parenchymatous elements. The structure described above in *P. johnsoni* is a distinctive muscular structure which is in some respects sphincter-like. However, its function is not known at present.

The species is named after Mr P. M. Johnson, National Parks and Wildlife Service, Pallarenda, Queensland, in appreciation of help given in collecting specimens.

Progamotaenia bancrofti (Johnston, 1912)
FIGS 16–23

Material examined: from *Onychogalea fraenata*: 2 specimens, Dingo, Qld, 12.vii.1975, J. E. Nelson; 1 specimen, Dingo, Qld., (captive animal) March, 1978, I. Beveridge.

From *Onychogalea unguifera*: 6 specimens, Wernadinga Station via Burketown, Qld, 6.viii.1979, R. Speare and P. M. Johnson; 8 specimens, Chadshunt Station via Mt Surprise, Qld, 7.viii.1979, R. Speare and P. M. Johnson; 2 specimens, 'Kimberley Ranges', W.A., 31.viii.1976, L. Keller.

Description: Length 198–312 (243); width 9–18 (14); scolex diameter 2.21–2.75 (2.46); sucker diameter 1.05–1.38 (1.25) x 0.88–1.28 (1.02); no. proglottides 643–672 (660); mature proglottides 6.6–9.5 (7.9) x 0.34–0.42 (0.38); gravid proglottides 9.2–10.6 (9.8) x 0.40–0.70 (0.55); cirrus sac in mature proglottides 0.66–1.52 (1.11) x 0.23–0.34 (0.26); cirrus sac in gravid proglottides 1.4–1.9 (1.6) x 0.26–0.32 (0.29); no. testes per proglottis c. 200; testis diameter 0.06–0.09 (0.07); ovary 0.60–0.80 (0.67) x 0.24–0.35 (0.29); vitellarium 0.40–0.57 (0.47) x 0.14–0.24 (0.18); Mehlis' gland 0.11–0.17 (0.14); dorsal osmoregulatory canal 0.02–0.06 (0.04); ventral osmoregulatory canal 0.22–0.35 (0.30); egg 0.036–0.041 (0.039); embryophore 0.017–0.024 (0.018); oncosphere 0.014–0.020 (0.016).

Large, broad, ribbon like worms. Scolex large, globular, distinctly demarcated from scolex. Four cup-shaped suckers embedded within scolex. Neck absent. Proglottides greatly extended transversely, craspedote, with broad, fleshy, folded velum radiating outwards from strobila, covering ¼ to ⅓ of the adjacent proglottis. Mature proglottides with approximate length: width ratio of 1:20 to 1:23. Gravid proglottides with ratio 1:16 to 1:20. Terminal proglottides narrower with ratio 1:8.

Figs 16-23. *Progamotaenia bancrofti* (Johnston). 16. scolex; 17. transverse histological section through cortex showing musculature; 18, 19. eggs showing variation in shape and in thickness of embryophore; 20. lateral region of mature proglottis; 21. female genital complex, from hand cut transverse section; ventral towards top of page; 22. postmature proglottis showing tubular uterus; 23. gravid proglottis. Scale lines, figs 16, 23, 1.0 mm, figs 18, 19, 0.01 mm, figs 17, 20-22, 0.1 mm.

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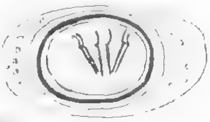

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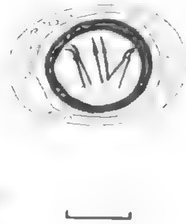

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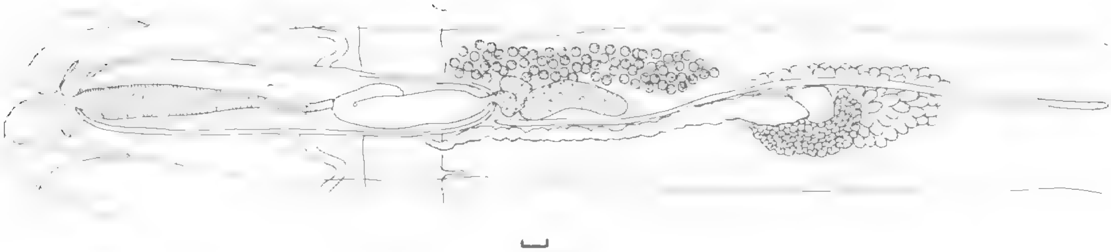

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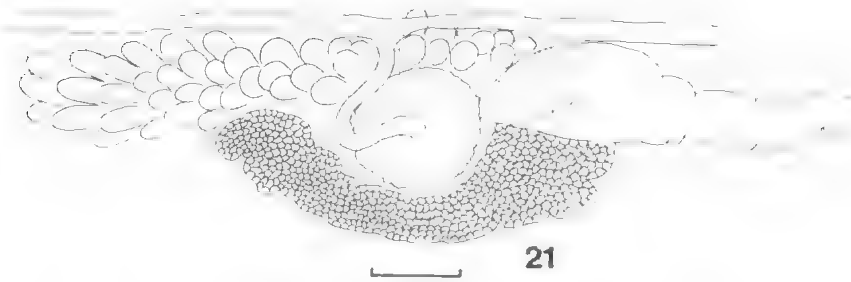

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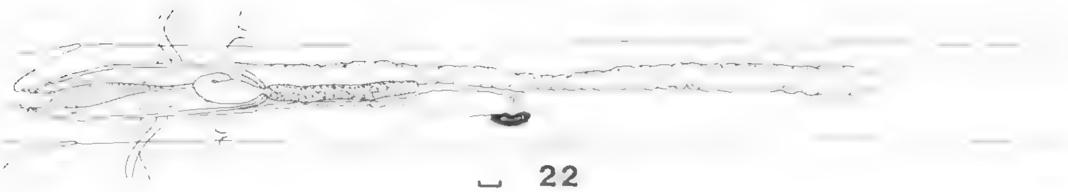

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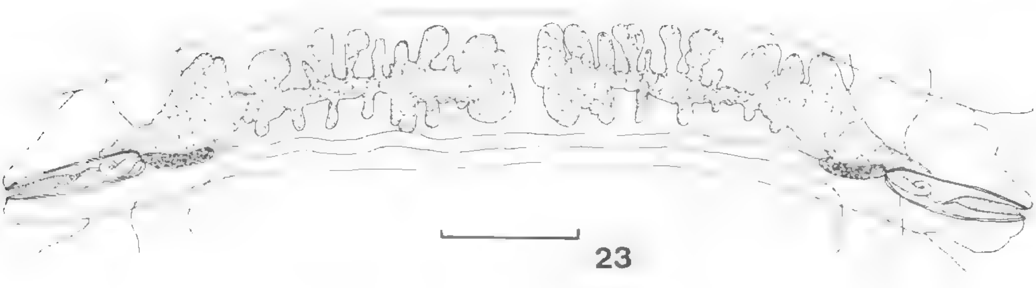

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Longitudinal musculature powerfully developed, composed of pallisades of muscle bundles. Bundles elongate, arranged radially, bundles towards periphery smaller, with fewer fibres. Transverse muscles well developed, forming a dense band along cortico-medullary junction. Dorso-ventral fibres prominent, crossing cortex and medulla at regular intervals. Longitudinal osmoregulatory canals paired. Ventral canal wider than dorsal canal, situated medial to it. Small accessory canal associated with ventral canal, on ventral side of ventral canal. Transverse canal connects left and right ventral canals at posterior margin of each proglottis. Complex of very fine branching and anastomosing vessels associated with dorsal system at posterior margins of proglottides. In scolex, vessels lead to connecting ring vessel in transverse plane at level of anterior margins of suckers. Genital ducts cross osmoregulatory canals dorsally. Genital atrium shallow, with corrugated walls, opening in middle of lateral proglottis margin, causing interruption of velum. Cirrus sac powerfully developed with thick muscular walls, extends beyond osmoregulatory vessels into medulla. Cirrus widest at distal extremity, heavily armed with spines; mid-region coiled, unarmed. Internal seminal vesicle present, usually reflexed distally when filled. External seminal vesicle large, elongate, covered externally with layers of glandular cells. Vas deferens inconspicuous, coils anteriorly to testes. Vasa efferentia not seen. Testes distributed in two compact groups anterior to cirrus sac, extending from longitudinal osmoregulatory canals to lateral margin of ovary. Testes in 3–5 longitudinal and 4–6 transverse rows. Number of testes in each group could not be counted accurately.

Vagina tube-like opening to genital atrium posterior to cirrus sac, distal vagina seen only in serial sections. Vagina leads medially along ventral aspect of cirrus sac, crosses to dorsal aspect of medulla, gradually increasing in diameter. Seminal receptacle not clearly separated from vagina, situated lateral to vitellarium. Ovary fan shaped, composed of numerous clavate lobules, on ventral aspect of medulla. Vitellarium reniform, dorsal and posterior to ovary, partially enclosing Mehlis' gland, which is spherical, anterior to vitellarium.

Uterus transverse, tube-like, paired in each proglottis, dorsal to ovary. Tubular uterus extends from near proglottis midline, anterior to vitellarium and dorsal to ovary, runs along ventral aspect of medulla almost to longitudinal osmoregulatory canals. Fully developed uterus sacciform, with prominent anterior diverticula, and fewer, smaller posterior diverticula; crossing longitudinal osmoregulatory canals dorsally, extending to postero-lateral corners of proglottides. Egg elongate ovoid, outer wall thin. Pyriform apparatus absent, even in eggs from faeces; embryophore surrounding egg thick, ellipsoidal.

First mature proglottis 165–235th; filling of seminal receptacle occurs at approximately same time as sperm appears in internal seminal vesicle; vagina does not atrophy following insemination; uterine filling commences in c. 300th proglottis.

Discussion: The descriptions of *Progamotaenia bancrofti* by Johnston (1912), Nybelin (1917) and Beveridge (1976), are unsatisfactory because only a limited number of specimens was available. The original description by Johnston (1912) was based on a single non-gravid specimen from *Onychogalea fraenata*, the description by Nybelin (1917) was based on four specimens from *O. unguifera*, all of which were severely contracted, and only one was gravid. Beveridge (1976) re-examined all these specimens but was able to add little. The type host, *O. fraenata* is now almost extinct, so that the main source of material for the present re-description came from the related wallaby, *O. unguifera.*

Although ample material was available, the species is extremely difficult to examine because of its large size and the thickness of the longitudinal musculature and velum. Nevertheless, the present re-description supports earlier descriptions in most respects, differing only in the features of the uterus and external seminal vesicle. The uterus commences development as a transverse tube, gradually enlarging in diameter as it fills with eggs. In postmature proglottides, in which the ovary has involuted, the uterus remains tube-like, with little evidence of anterior and posterior diverticula. The latter develop subsequently in gravid proglottides. The lack of diverticula on the uteri of the holotype described by Beveridge (1976), presumably reflects the immaturity of the specimen rather than a significant difference between it and the new material.

A prostate at the proximal pole of the cirrus sac was described in *P. bancrofti* by Nybelin (1917) and Beveridge (1976). The structure

is in fact an external seminal vesicle, differing from comparable structures in congeners in being elongate rather than ovoid, and surrounded by a mass of glandular cells. This latter feature serves to separate *P. bancrofti* from all congeners except *P. johnsoni*. However, here the term "prostate" has been discarded in favour of "external seminal vesicle" to avoid confusion with a structure (also termed the prostate) described in certain species of the anoplocephalid genera *Andrya* Railliet 1893 and *Diandrya* Darrah 1930. Rausch (1976) has cast considerable doubt on the existence of a prostate in these genera, suggesting that the organ in question is the external seminal vesicle.

Nybelin (1917) stated that a pyriform apparatus was not present, but Beveridge (1976) cautioned that the few specimens available to Nybelin may not have been fully gravid. In the new material, a pyriform apparatus was found neither in the terminal proglottides of strobilae which were fully gravid, nor in shed proglottides collected from the large intestine of the host. It was not established whether a pyriform apparatus develops in the external environment following voiding. The only congener in which a pyriform apparatus is lacking is *P. lagorchestis*. In both species the egg is elongate rather than spherical or ovoid.

Serial longitudinal sections of the strobila revealed that the distal vagina is an extremely narrow duct, but that it remains patent even in proglottides in which the uterus is in the process of filling. The distal vagina was not seen in every proglottis, but in a sufficient number to indicate that earlier descriptions have been incorrect, and that the distal vagina is merely difficult to find, even in sections, rather than having atrophied following insemination.

Further collecting has confirmed *Onychogalea fraenata* and *O. unguifera* as hosts of *P. bancrofti*. The species has not been found in *Wallabia bicolor* or *Setonix brachyurus* apart from a single report by Sandars (1957). Her brief descriptions do not conform to earlier more detailed descriptions (Beveridge 1976). The location of Sandars' specimens is unknown, and their identifications may be in error.

P. bancrofti was present in seven of ten *O. unguifera*, with either one or two cestodes per wallaby. The cestodes occurred in the ileum.

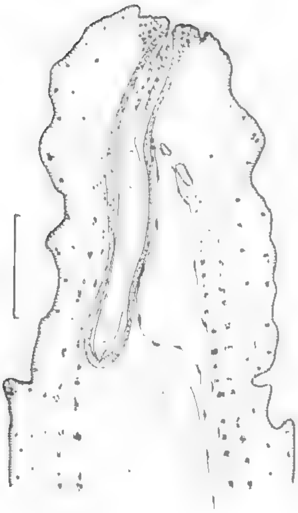
Progamotaenia diaphana (Zschokke, 1907)
FIGS 24–29

Material examined: types from *Lasiorhinus latifrons*; numerous fragmented specimens, from bile ducts, Swan Reach, S.A., 12.v.1977, I. Beveridge; 14.ix.1978, M. Gaughwin.

Description: Length up to 102; width to 2; scolex diameter 0.32–0.46 (0.38); sucker diameter 0.13–0.16 (0.15); neck 0.07–0.16 (0.11); mature proglottides 1.1–1.9 (1.5) x 0.23–0.43 (0.31); gravid proglottides 1.7–2.6 (2.0) x 0.28–0.35 (0.34); cirrus sac in mature proglottides 0.17–0.39 (0.29) x 0.06–0.09 (0.07); cirrus sac in gravid proglottides 0.22–0.33 (0.28) x 0.04–0.09 (0.07); no. testes per proglottis 39–64 (51); testis diameter 0.04–0.05 (0.04); ovary 0.08–0.14 (0.11) x 0.04–0.10 (0.08); vitellarium 0.06–0.08 (0.07) x 0.04–0.06 (0.05); Mehlis' gland 0.04–0.05 (0.05); dorsal osmoregulatory canal 0.01–0.02 (0.02); ventral osmoregulatory canal 0.02-0.04 (0.03); egg 0.07–0.08 (0.08); pyriform apparatus 0.04–0.05; oncosphere 0.03.

Small, fragile worms, almost transparent and easily broken when fresh. Scolex prominently four lobed, with each muscular, cup shaped sucker borne on arm like extentions of scolex. Scolex frequently, but not invariably dark, pigmented. Pigment distributed mainly on arms and at apex of scolex, as masses of small, brown staining accumulations of granules in the cortex immediately below the tegument. Small pigmented granules scattered around vicinity of central nervous system. Neck present in relaxed specimens. Proglottides extended transversely, craspedote, with narrow (c. 0.05) straight-edged velum overhanging adjacent proglottis. Mature proglottides with approximate length: width ratio of 1:2.5 to 1:8. Gravid proglottides with ratio 1:5.5 to 1:7.5. Longitudinal muscles poorly developed, composed of 2 rings of fibre bundles with 2 to 8 fibres per bundle. Transverse muscle consists of individual fibres running along cortico-medullary junction. Dorso-ventral muscle fibres single, crossing cortex and medulla at irregular intervals.

Longitudinal osmoregulatory canals paired. Ventral canal wider than dorsal canal, situated medial to it. Two transverse canals connect left and right osmoregulatory canals at posterior margin of each proglottis. Canal connecting ventral vessels of moderate size, readily observed; canal connecting dorsal vessels minute, seen only with difficulty. Junction



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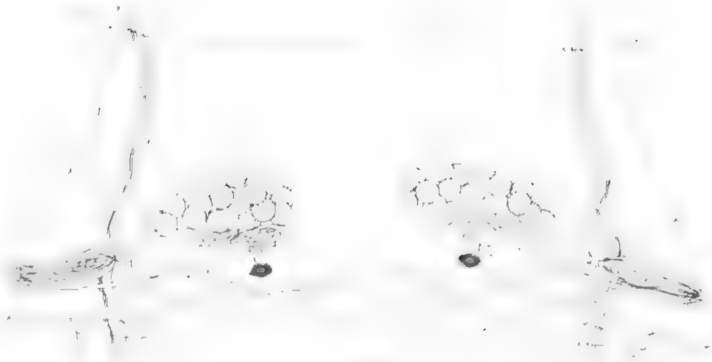

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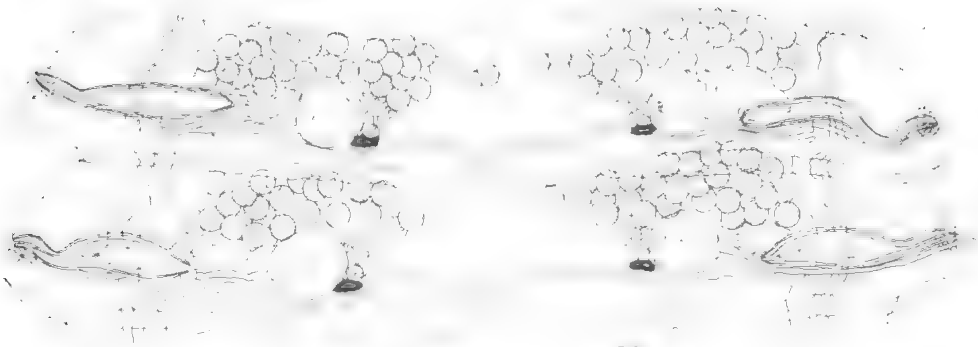

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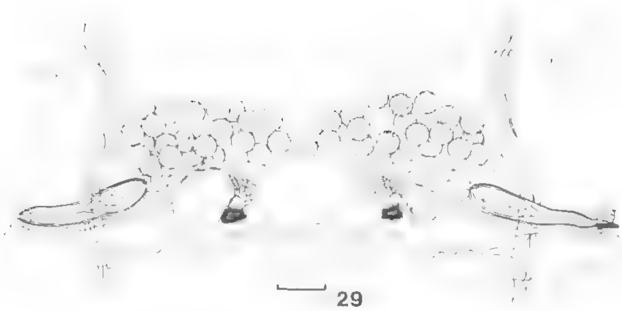

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of osmoregulatory canals in scolex not seen. Genital ducts cross osmoregulatory canals dorsally. Genital atrium of insignificant size, sometimes situated on small genital papilla. Atrium in posterior part of lateral proglottis margin, dividing margin in ratio of 1:2 to 1:3. Cirrus sac narrow, clavate, musculature of walls weakly developed, always reaching and usually extending beyond longitudinal osmoregulatory canals. Cirrus narrow, uncoiled, armed with minute spines, only clearly visible on exerted cirri. Prominent internal seminal vesicle present. External seminal vesicle large, ovoid, extending to lateral margin of, or occasionally anterior to, seminal receptacle. Vas deferens coiled, passes anteriorly, diminishing in diameter. Vasa efferentia not seen. Testes distributed between lateral osmoregulatory canals anterior to female genitalia. Testes either in two groups extending from longitudinal canals to medial side of female genitalia, or in continuous band across proglottis, with testes more numerous in lateral parts of band. Both forms of testis arrangement occur together in some strobilae. Vagina tube-like, opening to genital atrium posterior to cirrus sac. Vagina leads medially to large ovoid, thin-walled seminal receptacle. Ovary fan-shaped, composed of numerous, clavate lobules, on ventral aspect of medulla. Vitellarium ovoid or reniform, posterior and dorsal to ovary. Mehlis' gland spherical, anterior to vitellarium, dorsal to ovary. Uterus transverse, tube-like, paired in each proglottis, anterior to seminal receptacle and ovary. Fully developed uterus sacciform, without diverticula, crossing longitudinal osmoregulatory canals dorsally and reaching postero-lateral corner of proglottis. Uteri of proglottis may fuse in mid-line on rare occasions. Egg spherical, thick-shelled. Pyriform apparatus either conical or terminating in two horns, numerous reflexed filaments attached to apex of pyriform apparatus.

Sperm first appears in external and internal seminal vesicles in c.105th proglottis; seminal receptacle fills with sperm in c.110th proglottis, after male system commences to function. Vagina does not atrophy following insemination. Ovary fully developed from c.140th to 150th proglottis, involutes over 2–3 proglottides. Uterus begins to fill with eggs immediately after involution of ovary (c.150th).

Discussion: *Progamotaenia diaphana* was redescribed very briefly by Beveridge (1976) based on a single specimen assumed to be type material and a small number of fragmented specimens from a captive wombat. Although the latter collection suggested that *Lasiorhinus latifrons* might be the usual host of *P. diaphana*, no material had been seen from free-living hosts, and the very closely related cestode, *P. festiva*, had been collected from the bile ducts of free-living *Vombatus ursinus* (Beveridge 1976). Subsequently, collections of cestodes from *L. latifrons* in South Australia were tentatively identified as *P. festiva* (Rudolphi 1819) as they did not conform exactly to the description of *P. diaphana*, and doubt was thrown on the status of *P. diaphana* itself (Presidente & Beveridge 1978). Abundant collections now to hand indicate that *P. diaphana* is a distinctive form, probably warranting specific status, and that doubt as to the identity of Presidente & Beveridge's material was due to a lack of appreciation of the extent of variability in the species.

The present redescription differs from that of Beveridge (1976) in a number of points. A prominent external seminal vesicle was present in the new material, but was stated as being absent in the earlier description. The number of testes per group was previously reported as 17–21, but in the new material is 18–33 per group or 39–63 per proglottis. Part of this variability is due simply to variation between individual cestodes. In two strobilae examined, the range and mean number of testes per proglottis based on examination of 10 proglottides in each strobila was 52–63 (56) and 39–53 (46). Number of testes per proglottis in the related *P. festiva* is 70–130, so that in spite of the variability, testis number is still a useful method of distinguishing the species.

In the type specimen redescribed by Beveridge (1976) early insemination of proglottides was followed by vaginal atrophy. This phenomenon was not recorded in the orginal description (Zschokke 1907) and was not present in the other material described by Beveridge

Figs 24-29. *Progamotaenia diaphana* (Zschokke). 24. transverse histological section of lateral region of proglottis showing cirrus sac, uterus and musculature; 25. mature proglottis; 26. mature proglottides showing variation in proglottis shape and testis distribution; 27. gravid proglottis; 28. scolex; 29. mature proglottis showing variation in testis distribution. Scale lines 0.1 mm.

(1976). In the new material, insemination invariably occurs after the male reproductive system of a particular proglottis has started to function and vaginal atrophy never occurs following insemination. The distal vagina is frequently difficult to see in mounted specimens, so fragments of the type material were serially sectioned, showing that the vagina remained intact in post mature proglottides and suggesting that Beveridge's interpretation based on the single whole mount preparation was incorrect. Beveridge's (1976) suggestion that vaginal atrophy could vary within a species should therefore be ignored. The suggestion has also proven incorrect in the case of *P. lagorchestis* and *P. thylogale* (Beveridge & Thompson 1979); species which were initially confused under the one name.

Two diagrams of the egg of *P. diaphana* were given by Beveridge (1976), one showing the pyriform apparatus ending in two horns and the other showing an undivided pyriform apparatus. Both forms are present in the new material but, being unmounted, it is possible to roll the eggs under a coverslip and show that there are indeed two different types and that they are not the same form viewed from different aspects (Beveridge 1976). The undivided form is identical with that found in *P. festiva* and the divided form may merely be a developmental stage (Beveridge 1976), since it occurs in much lower numbers. This form of pyriform apparatus was illustrated by Böhm & Supperer (1958).

The presence of dark pigment in the scolex of *P. diaphana* was first reported by Böhm & Supperer (1958), and is present in the single scolex among the type material as well as in all lots of new material. The pigment, however, is not invariably present and cannot therefore be used as a distinguishing character.

Beveridge (1976) listed a number of features which distinguished *P. diaphana* from the related *P. festiva*. Of these, the presence of proterogyny and vaginal atrophy should be discarded, while the shape of the uterus requires a subjective assessment and is therefore of doubtful value. The two species differ in the frequent presence of dark pigment in the scolex of *P. diaphana* and differences in the number of testes per proglottis, allowing for the considerable variation which occurs in both species. In view of the present redescription, *P. diaphana* probably warrants continued specific rank, and the specimens described under the name *P. festiva* from *L. latifrons* by Presidente & Beveridge (1978) should be renamed *P. diaphana*. However, Beveridge (1976) has pointed to the extensive variation in specimens of *P. festiva* from various host species, and it is evident that a reassessment of this taxon and *P. diaphana* will be necessary when life histories are known and cross infection experiments can be undertaken.

The data presented above establish *L. latifrons* as the usual host for *P. diaphana*. Böhm & Supperer (1958) reported *P. diaphana* from a captive *Vombatus ursinus* in Europe, but subsequent correspondence by a colleague with Supperer established that this animal was in fact *L. latifrons* (Presidente & Beveridge 1978), and had earlier been misidentified. In his original description, Zschokke (1907) gave no details as to how he obtained his specimens, and gave the host name as *Phascolomys wombat*, a name which is now placed as a synonym of *V. ursinus*, but which could have been applied to any of the species of wombats. If, as indicated by data associated with the material considered now to be type material, the species was initially collected by E. Angas Johnston, then *L. latifrons* may be the type host. Angas Johnston was a doctor and amateur naturalist who lived in Adelaide.

Progamotaenia zschokkei (Janicki, 1909)

Material examined: From *Onychogalea fraenata*: 1 specimen, Dingo, Qld, 12.vii.1975, J. E. Nelson; 5 specimens, captive animals originating from Dingo, Qld, March 1978, 19.ii.1979, I. Beveridge; 8 specimens, same data, 26.vii.1979, R. Speare. From *Onychogalea unguifera*: 4 specimens, "Kimberley Ranges", W.A., 31.viii.1976, 6.xii.1976, L. Keller; 2 specimens, Chadshunt Stn, Qld, 6.viii.1979, R. Speare and P. M. Johnson. From *Lagorchestes conspicillatus*: 5 specimens, Inkerman St, Qld, 7.ix.1979, 1.ii.1979, P. M. Johnson; 3 specimens, Mingela, Qld, 10.v.1979, I Beveridge. From *Thylogale stigmatica*: 10 specimens, El Arish, Qld, 30.vii. 1978, I. Beveridge. From *Petrogale penicillata*: 3 specimens, Hervey's Range, Townsville, Qld, 3.iv.1979, I. Beveridge. From *Macropus agilis*: 5 specimens, Marrakai Plains, N.T., 29.ix.1973, L. Corner; 13 specimens, Townsville, Qld, 15.vi.1978, I. Beveridge.

Discussion: Onychogalea fraenata, O. unguifera and *Macropus agilis* are new hosts for *Progamotaenia zchokkei*. Part of the material listed above from *M. agilis* was identified erroneously as *P. lagorchestis* by Beveridge

(1976). *M. agilis* is not a host of *P. lagorchestis* or of *P. thylogale*, a species which was confused under the former name by Beveridge (1976). Further specimens of *P. zschokkei* from *Thylogale stigmatica* and *Petrogale penicillata* confirm earlier reports from these hosts based on rather poorly preserved material (Beveridge 1976).

There was considerable size variation in the specimens of *P. zschokkei* examined. Those from *O. fraenata* measured 95–120 x 11–12 mm; specimens from *O. unguifera* were larger, measuring 380–460 x 8–12 mm. Specimens from *L. conspicillatus* were 160–170 mm long and varied from 8–13 mm in width. Cestodes from *M. agilis* were long (130–185 mm) but only 4–6 mm wide while specimens from *P. penicillata* and *T. stigmatica* were the smallest, measuring 58–61 x 2–3 mm and 50–90 x 2–3 mm respectively. In spite of the great difference in size, there were no significant differences in internal morphology. The size difference may be due to the influence of the host, but experimental infections will be needed to demonstrate whether this is the cause of the observed differences, or whether a species complex exists. Similar size variation has been noted in *P. festiva* and *P. macropodis* (Beveridge 1976).

Acknowledgments

Thanks are due to M. Gaughwin, R. Speare and P. M. Johnson for collecting specimens, or for supplying wallabies for dissection.

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BEVERIDGEA NEW GENUS (NEMATODA: STRONGYLIDA) FROM THE AGILE WALLABY FROM NORTHERN AUSTRALIA

BY PATRICIA M. MAWSON

Summary

Beveridgea n.g., type species B. corneri, n.sp., is close to Cloacina, differing chiefly in the much longer buccal capsule, and in the shape of the bursa, which is not joined ventrally. B. corneri has been taken from Macropus agilus, only on Cape York Peninsula, Queensland.

BEVERIDGEA NEW GENUS (NEMATODA: STRONGYLIDA) FROM THE AGILE WALLABY FROM NORTHERN AUSTRALIA

by PATRICIA M. MAWSON*

Summary

MAWSON, P. M. (1980) *Beveridgea* new genus (Nematoda: Strongylida) from the Agile Wallaby from northern Australia. *Trans. R. Soc. S. Aust.* 104(4), 81-82, 30 May, 1980.

Beveridgea n.g., type species *B. corneri*, n.sp. is close to *Cloacina*, differing chiefly in the much longer buccal capsule, and in the shape of the bursa, which is not joined ventrally. *B. corneri* has been taken from *Macropus agilis*, only on Cape York Peninsula, Queensland

Beveridgea n.g.

Cloacininae: cephalic roll well developed; submedian cephalic papillae elongate, bi-segmented; buccal capsule cylindrical, longer than its diameter, notched along anterior border; leaf crown of eight elements arising near anterior end of buccal capsule; cervical papillae thread-like; dorsal oesophageal gland opens into base of buccal cavity.

Male: spicules elongate, alate; bursa not deeply lobed, ventral lobes almost separate; ventral rays together, ventro-lateral ray separate from other laterals, externo-dorsal ray arises separately, dorsal ray divides twice. Gubernaculum present

Female: tail short, conical; vulva near anus, junction of ovejectors parallel with long axis of body.

Parasites of stomach of macropodid marsupials.

Type species: *B. corneri* n. sp.

Beveridgea has been referred to the Cloacininae *sensu* Lichtenfels (1980) because of the type of leaf crown and cephalic papillae, and the fact that the dorsal oesophageal gland opens directly into the base of the buccal cavity. It is distinguished from *Cloacina* Linstow, 1898, mainly by characters of the buccal capsule, which is longer, and of the leaf crown, the elements of which arise from the anterior end of the capsule wall; moreover, in *Cloacina* the ventral lobes of the bursa are joined.

Beveridgea corneri n.sp.

FIGS 1-7

Host and localities: Macropus agilis Gould. From Elizabeth Downs Station (type locality) and from Stones Crossing, Wenlock R., Qld. Holotype male and allotope female deposited in South Australian Museum (V1910).

This species was taken from at least three host animals, but very few were present in each; all are young worms, the females without eggs in the uteri. The species has not been found among stomach worms from *M. agilis* from more southerly parts of Queensland or from the Kimberley District of W.A.

Length of males 4.7-5.7 mm, females 4.9-5.3 mm. Labial collar well developed, slightly lobed anteriorly. Cephalic papillae of two segments, distal distinctly shorter than proximal. Buccal capsule 40-50 μm long, its anterior border notched, its posterior border lobed, following contour of anterior end of oesophagus. Eight elements of leaf crown arise from anterior $\frac{1}{6}$ of wall of buccal capsule, and end in points around mouth. In posterior $\frac{1}{4}$ of buccal capsule small irregularly placed denticles project into buccal cavity. Oesophagus 480-520 μm long in male, 440-550 μm in female, cylindrical in anterior half, then slight swelling precedes position of nerve ring, and posterior portion widens towards base. In median swelling small tooth projects into lumen. Dorsal oesophageal gland distinct, opening on a prominence at anterior end of dorsal section of oesophagus.

Nerve ring lies just posterior to median swelling of oesophagus; excretory pore near base of oesophagus; thread-like cervical papillae 125-130 (♂) and 120-140 (♀) from anterior end.

Male: bursa with characters of genus. Dorsal ray divides just before midlength, and final branches very short. Genital cone short, flanked by two lateral "balloons" of apparently inflated cuticle. From base of dorsal ray single digitiform 'papilla' projects into cavity of bursa (Fig. 6).

Female: tail 150-200 μm long, vulva 220-310 μm from posterior end. Eggs absent.

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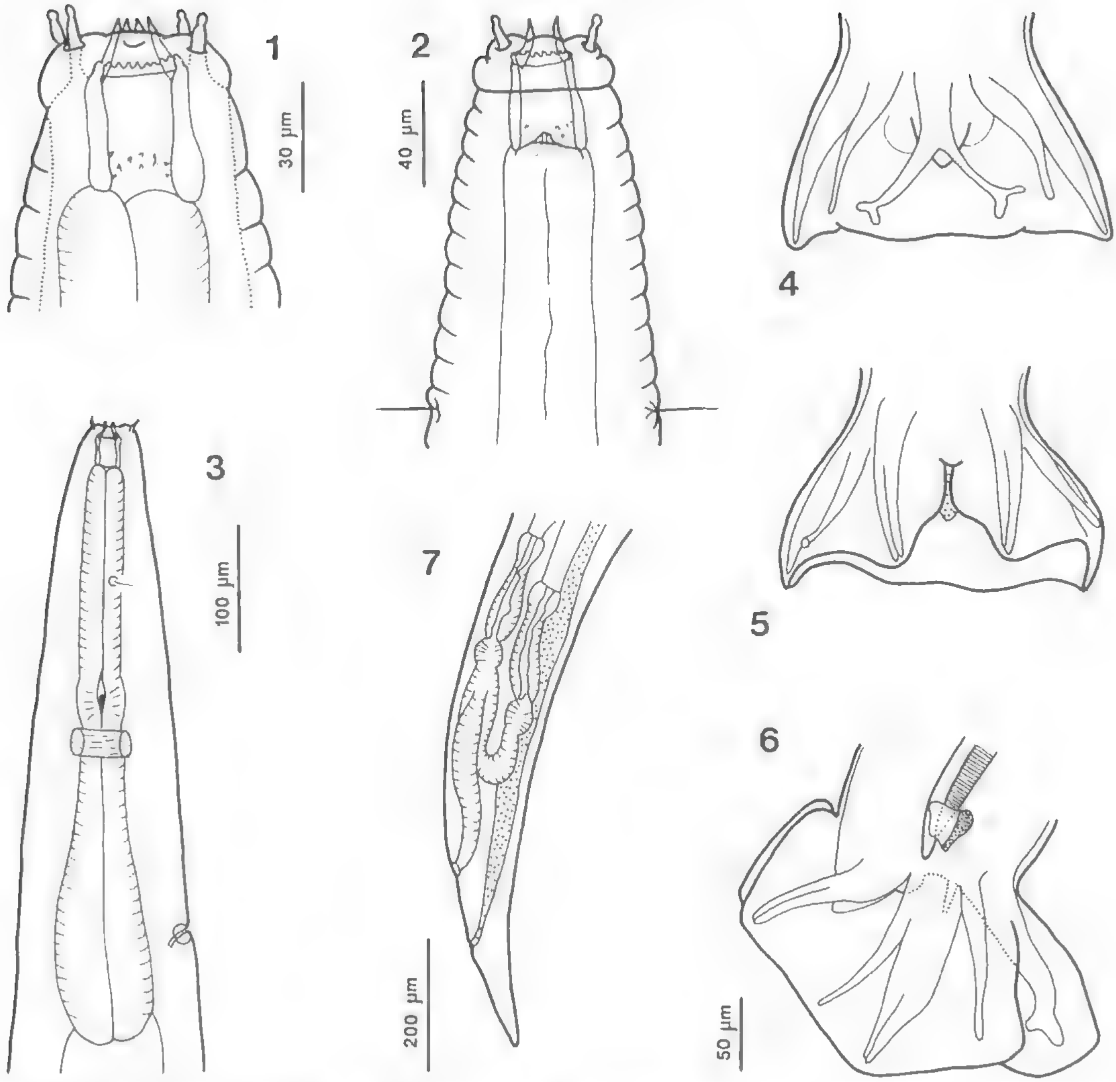

Figs 1-7, *Beveridgea corneri* n.sp. 1 head, lateral view; 2. anterior end, dorsal view; 3. oesophageal region; 4, 5 and 6, bursa in dorsal, ventral, and lateral views respectively; 7. posterior end of female. (Figs 4-6 to same scale).

Acknowledgments

The material for this study was kindly given to me by Dr I. Beveridge (then of the Dept of Tropical Veterninary Science, James Cook University of North Queensland). It was collected by him and by L. Corner.

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NON-MARINE MOLLUSCS FROM DOLOMITIC LIMESTONES IN THE NORTH OF SOUTH AUSTRALIA

BY N. H. LUDBROOK

Summary

Non-marine molluscs, from the type section of the Etadunna Formation at Lake Palankarinna (KOPPERAMANNA 1:250 000 map sheet), and from dolomitic limestones on the BILLA KALINA and TARCOOLA 1:250 000 map sheets are described and correlated with those occurring in northern Australia. Etadunna Formation molluscs from Lake Palankarinna are land snails – Bothriembryon praecursor and Meracomelon lloydi – while those from near "Billa Kalina" and "Malbooma" and also from Lake Woorong on the COOBER PEDY 1:250 000 map sheet are freshwater species of Syrioplanorbis, Physastra and Rivisessor. The dolomitic limestones are considered to be of Miocene age.

NON-MARINE MOLLUSCS FROM DOLOMITIC LIMESTONES IN THE NORTH OF SOUTH AUSTRALIA

by N. H. LUDBROOK*

Summary

LUDBROOK, N. H. (1980) Non-marine molluscs from Miocene dolomitic limestones in the north of South Australia. *Trans. R. Soc. S. Aust.* **104**(4), 83-92, 30 May, 1980.

Non-marine molluscs, from the type section of the Etadunna Formation at Lake Palankarinna (KOPPERAMANNA 1:250 000 map sheet), and from dolomitic limestones on the BILLA KALINA and TARCOOLA 1:250 000 map sheets are described and correlated with those occurring in northern Australia. Etadunna Formation molluscs from Lake Palankarinna are land snails — *Bothriembryon praecursor* and *Meracomelon lloydi* — while those from near "Billa Kalina" and "Malbooma" and also from Lake Woorong on the COOBER PEDY 1:250 000 map sheet are freshwater species of *Syrioplanorbis*, *Physastra* and *Kirlsessor*. The dolomitic limestones are considered to be of Miocene age

Introduction

In describing fossil non-marine molluscs from northern Australia, McMichael (1968) cited some of the species as occurring also in the "Etadunna Formation, Billa Kalina Station, South Australia." Tabulating the localities, lithology and faunas of samples examined by McMichael, Lloyd (1968) similarly attributed to the Etadunna Formation, Tirari Desert, three species, two of which came from Lake Palankarinna and one from Billa Kalina. The present paper seeks to correct the unfortunate confusion of two widely separate localities, shown on Figure 1, and to distinguish between those molluscs which occur in the type section of the Etadunna Formation at Lake Palankarinna and those in the dolomitic limestones cropping out north of "Billa Kalina" Homestead. The fossil content of dolomitic limestones from near "Malbooma O.S." is also placed on record.

All the material studied is in the Palaeontological Collection of the Geological Survey of South Australia. All map references are to the Geological Atlas Series.

Specimens from both Lake Palankarinna and north of "Billa Kalina" were sent to McMichael at the Australian Museum in 1963 with references to published data on the Etadunna Formation and a note to the effect that "the dolomite containing *Planorbis* from Billa Kalina is not necessarily to be correlated with the Etadunna." In official correspondence, McMichael tentatively identified the Etadunna gastropods respectively as belonging to the genus *Bothriembryon* and similar to land snails of the genera *Meracomelon* and *Sinumelon*, probably the former, and the material from Billa Kalina as a large *Planorbis*-like shell.

In 1965, Etadunna specimens were again sent to McMichael to supplement his studies of the northern Australian fauna. No material from Billa Kalina was included. McMichael's (1968) reference to the occurrence of certain species in the "Etadunna Formation, Billa Kalina Station" seems to originate in notes he made in 1963 when he had specimens from both localities.

One of the unfortunate consequences of the error is that the gastropods of the type section of the Etadunna Formation at Lake Palankarinna have been only obscurely recorded. Moreover, the molluscs from the Etadunna Formation are land snails, while those from Billa Kalina are freshwater. The only limestones containing both land and freshwater molluscs (tabulated by Lloyd 1968) appear to be in the Deep Well area of Central Australia and the Carl Creek Limestone of the Riversleigh area, Queensland

Molluscs from the Etadunna Formation

The molluscs from Lake Palankarinna, south of Cooper Creek, 23 km SW of "Etadunna" (lat. 28°48'S, long. 138°25'E, locality sample number 6540 RS 39, KOPPERAMANNA 1:250 000 map sheet) were collected by R. H. Tedford from nodular dolomitic limestone at the base of member 2e, Etadunna Formation (Stirton *et al.* 1961). Additional specimens were collected by J. M. Lindsay in 1970. They therefore come from low in the formation, some 5 m above the base, although gastropods have been recorded by Stirton and his col-

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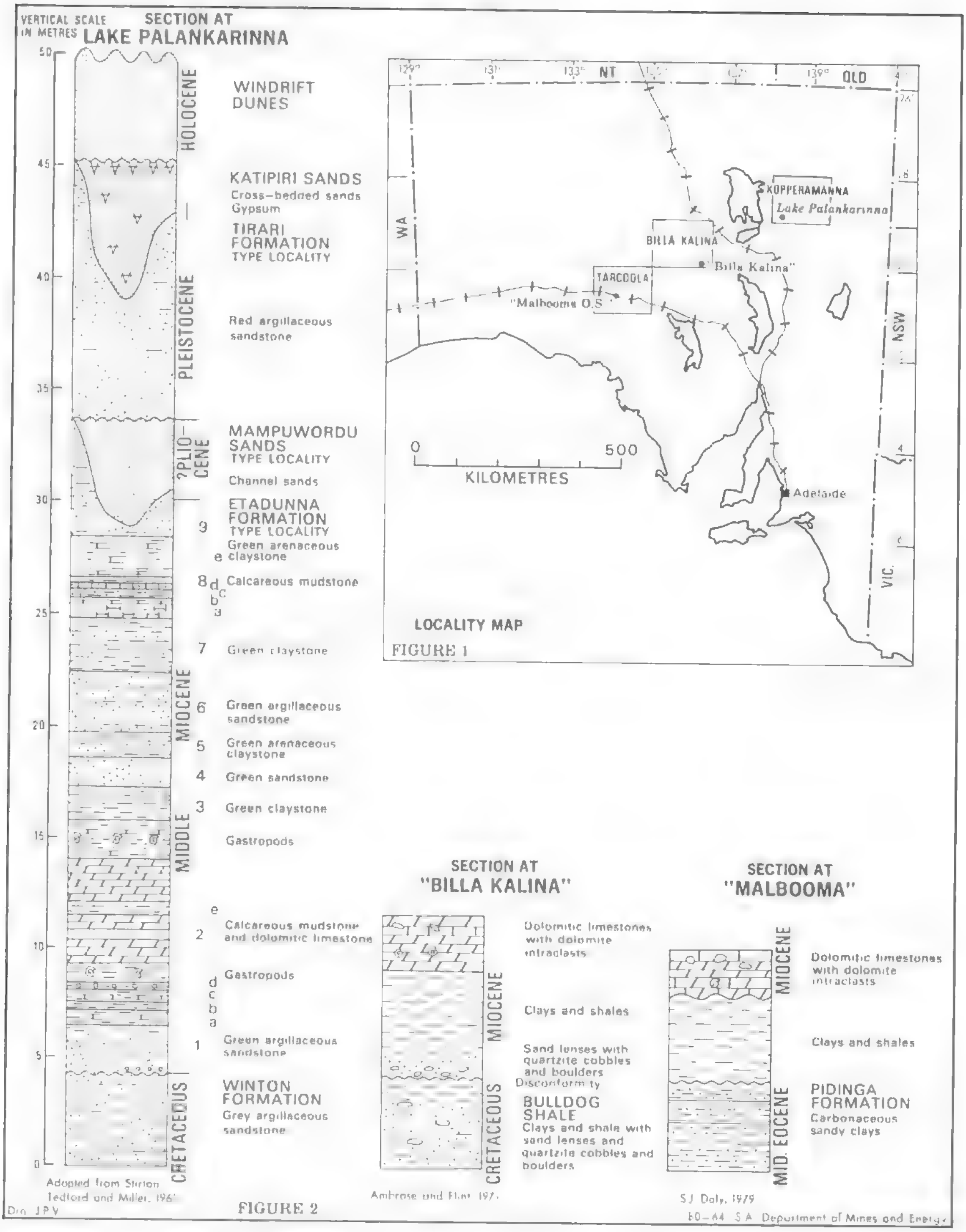

FIGURE 1

FIGURE 2

leagues from calcareous mudstones at both the base and top. The measured stratigraphic type section at Lake Palankarinna, redrawn after Stirton *et al.*, is shown in Figure 2.

In the opinion of Stirton *et al.* (1961), the sequence of dolomitic limestones, calcareous mudstones and claystones with intraformational breccias represents deposition in a shallow-water lagoon with repeated exposure and drying. The green claystones and argillaceous sandstones have yielded the important Ngapakaldi vertebrate fauna which contains lungfish and water birds. It includes also diprotodonts and macropodids which appear to have been entrapped in boggy clay. Gastropods in the dolomitic limestones are in the form of moulds and casts, many of which are freed from the matrix. They seem to be locally common and gregarious, but belong to only two species, *Bothriembryon praecursor* McMichael and *Meracomelon lloydi* McMichael. Both species are related to land snails typically inhabiting arid parts of the State — *Bothriembryon barretti* the Nullarbor Plain and *Meracomelon* spp. the Northern Flinders Ranges. As no freshwater shells have so far been found with them, they are presumed to represent the drying-out periods of deposition of the Etadunna Formation postulated by Stirton and his colleagues.

The possible relationships between land snails from non-marine deposits in and near Hobart and species of *Bothriembryon* and *Meracomelon* occurring in the Etadunna Formation were considered by McMichael. Examination of the limited amount of material now available from Hobart, discussed in the systematic section, has failed to establish similarity between the Tasmanian species in the Geilston Travertine and those from the Etadunna Formation.

Molluscs from the Billa Kalina area

The following description of the planorbid-bearing limestones from north of "Billa Kalina" Homestead (locality and sample numbers 6138 RS 62-73, 87, BILLA KALINA 1:250 000 map sheet, lat. 29°53'S, long. 136°11'E) is modified from Ambrose & Flint (1979)[1].

Tertiary sediments near "Billa Kalina" form a thin capping, maximum thickness 13 m, on shales and conglomeratic sands of Early Cretaceous Bulldog Shale. A resistant dolomitic limestone within the Tertiary sequence overlying the more-easily eroded shales results in flat-topped plateaux and mesas.

An idealised sequence (Fig. 2) comprises a very thin basal sand horizon containing quartzite clasts derived from erosion of the Cretaceous sediments. This is overlain by approximately 5 m of green dolomitic and occasionally palygorskite-bearing clays, which are in turn overlain by 1.5 m of white fossiliferous limestones and dolomitic limestones.

Samples with planorbids, to which the number 6138 RS 87 has been assigned, were first collected from these limestones in 1958 by H. G. Roberts during reconnaissance mapping for Clarence River Oil Syndicate. Subsequent collections (6138 RS 62-73, containing hydrobiids) were made in 1979 by G. J. Ambrose and R. B. Flint during mapping of the BILLA KALINA 1:250 000 map sheet from three localities within a distance of 1.5 km from 3.5-4.0 km NNW to N of "Billa Kalina". The total amount of material is not large, and the known fauna is limited to four species—an undescribed species of *Rivisessor* occurring in samples 6138 RS 62-73, *Syrioplanorbis hardmani*, *Syrioplanorbis* sp., and *Physastra rodingae*, either in crowded masses or scattered throughout the matrix. These were freshwater inhabitants of or were washed into the Tertiary lake postulated by Ambrose and Flint.

The Tertiary sediments on Billa Kalina and Millers Creek Stations have been correlated, on a lithological basis, with the Etadunna Formation of the Lake Eyre Basin and the Namba Formation of the Tarkarooloo Basin (Jessup & Norris 1971; Ambrose & Flint 1979[1]). Jessup & Norris divided what they considered to be the Etadunna Formation in the Billa Kalina-Millers Creek area into two members — a lower Billa Kalina Clay Member and an upper Millers Creek Dolomite Member. A revision of this nomenclature is presently being prepared by Ambrose and Flint, and, pending its publication, the Billa Kalina Clay Member and the Millers Creek Dolomite Member are here regarded as units of an unnamed formation. The molluscs in the dolomites provide the only direct evidence so far obtained for correlating them with other formations of known Tertiary age.

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[1] Ambrose, G. J. & Flint, R. B. (1979). A regressive Tertiary lake system and silicified strand lines, Billa Kalina area, South Australia. S.A. Dept. Mines & Energy Rept 79/104 (unpublished).

Material from "Malbooma Outstation" area

Tertiary fossils were first collected in this area in 1979 by R. B. Flint, S. J. Daly and A. F. Crooks (locality and sample numbers 5736 RS 47-52 TARCOOLA 1:250 000 map sheet. lat. 30°39'S, long. 134°05'E). A brief geological description is provided by S. J. Daly: "Possible late Tertiary sediments west of "Malbooma O.S." crop out poorly, and form low rises which are veneered by calcrete. The best exposures are in railway cuttings on the Trans Australia Railway Line. The sequence, thought to be approximately 6 m thick, overlies carbonaceous sandy clays and sands of the Middle Eocene Pidinga Formation" (Fig. 2).

In a railway cutting 15.5 km west of "Malbooma O.S.", dark olive-green clays with red and yellow mottling are overlain by white-yellow fossiliferous dolomitic limestones which are fragmental at the top. The base of the sequence is not exposed. No fossils were previously known in the sequence".

The limestones are sparsely fossiliferous with scattered impressions, fragments and casts of *Rivisessor* sp. in a pelletal matrix. Occasional oogonia of a charophyte are also present. The environment was lacustrine, probably similar to and contemporaneous with that at "Billa Kalina".

Dolomitic limestone from Lake Woorong

In March 1980, fossiliferous dolomitic limestone (sample 5739 RS 23) was collected by M. C. Benbow, G. W. Krieg and P. A. Rogers from the southern lake of Lake Woorong, 32 km west of Lake Phillipson (lat. 29°36'06"S, long. 134°07'54"E, COOBER PEDY 1:250 000 geological map sheet). The hard dolomitic limestone, with dolomite clasts and occasional scattered casts and moulds of small gastropods, is similar to material collected from near "Billa Kalina". Although preservation is very poor, by analogy with the Billa Kalina and Malbooma material, the casts and moulds can be identified as the freshwater gastropods *Rivisessor* sp. and *Physastra rodingae*. The material was collected too recently for the locality to be included in either Figure 1 or Figure 2. COOBER PEDY adjoins TARCOOLA on the south and BILLA KALINA on the east.

Age and correlation of the dolomitic limestones

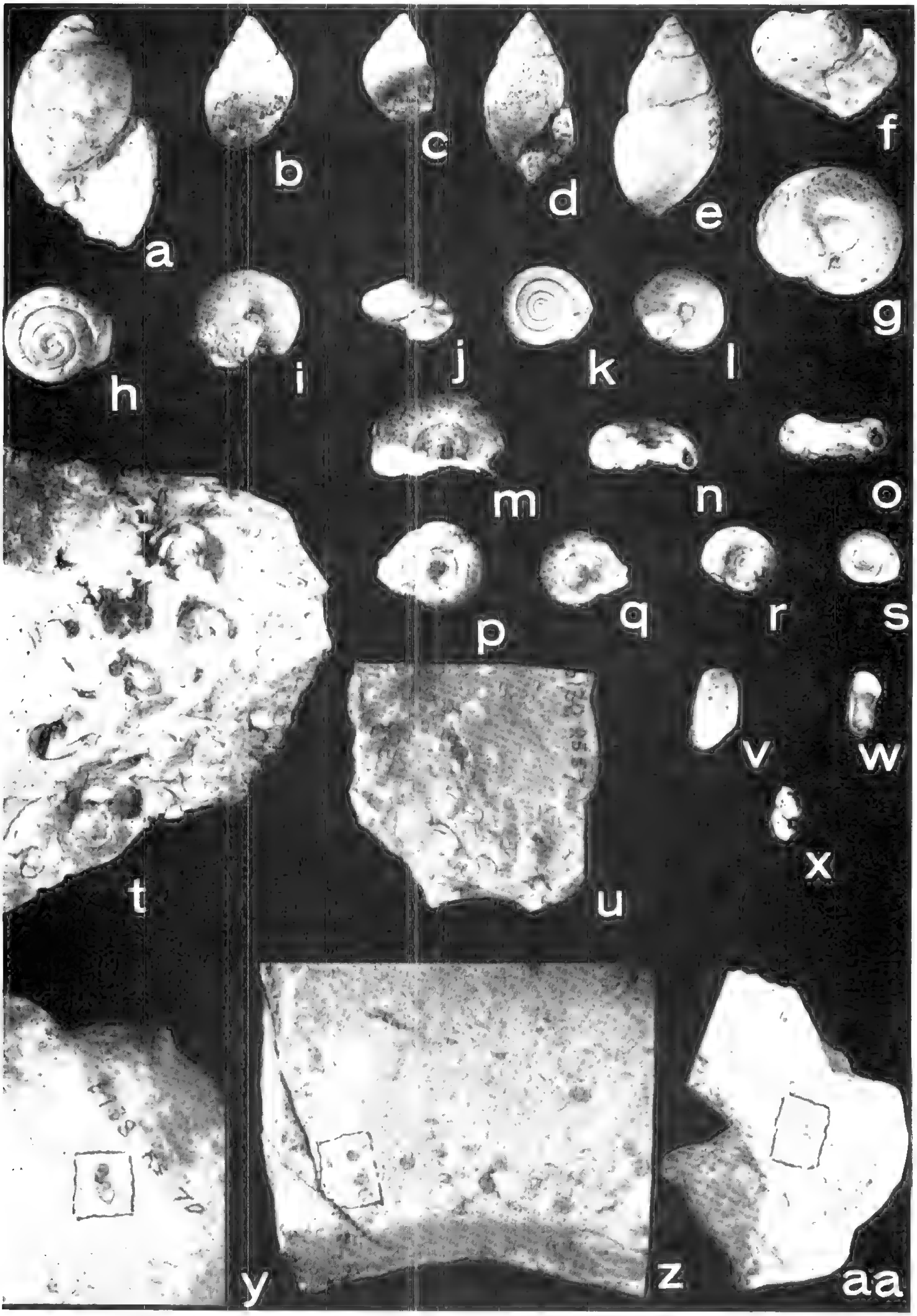
The age of the Etadunna Formation has been determined by W. K. Harris on unpublished palynological data as Middle Miocene (Callen & Tedford 1976, Callen 1977). The Etadunna land molluscs *Bothriembryon praecursor* and *Meracomelon lloydi* occur, either separately or together, in unnamed Tertiary limestones near "Deep Well" SSE of Alice Springs and in the Carl Creek Limestone N and SE of "Riversleigh," Queensland.

The molluscs in the limestones in the Billa Kalina, Malbooma and Lake Woorong areas are from a freshwater environment and do not provide direct correlation with the Etadunna Formation. They are related to one another by the presence of *Rivisessor* sp. The small assemblage of *Syrioplanorbis hardmani* and *Physastra rodingae* permits correlation of the dolomites near "Billa Kalina" with the White Mountain Formation of the Ord Basin in north-western Australia, the Arltunga Beds, unnamed limestones of the "Deep Well" area, in the Alice Springs area, and the Carl Creek Limestone, Horse Creek Formation and Brunette Limestone in Queensland. All of these have been regarded by Lloyd (1968) as of Miocene age but not necessarily correlates. The limestones at Billa Kalina and Malbooma are therefore considered to be also of Miocene age, but not necessarily exact correlates of the lower part of the Etadunna Formation.

Systematic descriptions

Class GASTROPODA
Subclass PROSOBRANCHIA
Order MONOTOCARDIA

Fig. 3 (a-e) *Bothriembryon praecursor*. Etadunna Formation, Lake Palankarinna. (a) M2738(1) x 1.2, large specimen. (b, c) M2738(3), showing faint internal spiral ribbing. (d, e) M2744(3), narrow specimen with axial ribs, a x 1.2. (f-l) *Meracomelon lloydi*, Etadunna Formation, Lake Palankarinna. (f) M2740, apertural view. (g) M2740, umbilical view. (h) M2741(1), apical view. (i) M2741(1) umbilical view. (j) M2743, apertural view. (k) M2743, apertural view. (l) M2743, umbilical view. (m-u) *Syrioplanorbis hardmani*, Billa Kalina (m-o) M2746(1), broken specimen giving natural section showing asymmetrical aperture. (p, q) M2746(2) lower and upper sides. (r, s) M2746(3) lower and upper sides. (t) M3579(1), (u) M3579(3) moulds and casts in limestone. (v, w) *Syrioplanorbis* sp., Billa Kalina (v) M3580(1), showing spiral ribbing. (w) M3580(2), showing symmetrical aperture. (x) *Physastra rodingae*, Billa Kalina, M3581(1). (y, z, aa) *Rivisessor* specimens in matrix. (y) 6138 RS 70, Billa Kalina. (z) 6138 RS 71, Billa Kalina. (aa) 5736 RS 48, Malbooma.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Suborder TAENIOGLOSSA = MESOGASTROPODA
Superfamily RISSOACEA
Family HYDROBIIDAE
Genus RIVISESSOR Iredale, 1943

Rivisessor sp.

FIGS 3y, z, aa

Material: Numerous specimens scattered throughout the matrix of samples 6138 RS 62-67 from 4 km NNW of "Billa Kalina", 6138 RS 68-70 from 3.5 km N of "Billa Kalina" and 6138 RS 71-73 from 4 km N of "Billa Kalina", casts and moulds in matrix of samples 5736 RS 47-51 15.5 km W of "Malbooma O.S." and 5736 RS 52 9 km W of "Malbooma O.S."

Description: Shell small, smooth, thick, solid, whorls 4 to 5, moderately tumid, suture impressed. Aperture oval, entire, oblique; last whorl 3/5 height of shell. Height 5, diameter 2.5, height of last whorl 3, height of aperture 1.5 mm. Maximum height estimated from an imperfect natural section 7, diameter 3 mm.

Distribution: Limestone cappings at Billa Kalina, localities 6138 RS 62-73 (BILLA KALINA 1:250 000 map sheet) and Malbooma, localities 5736 RS 47-52 (TARCOOLA 1:250 000 map sheet).

Habitat: Living species of *Rivisessor* commonly inhabit streams, lagoons and ponds.

Order BASOMMATOPHORA
Superfamily LYMNAEACEA
Family PLANORBIDAE
Genus SYRIOPLANORBIS Baker, 1945

Syrioplanorbis hardmani (Wade)

FIG 3 m-u

Planorbis hardmani McCoy. Hardman 1885: 7, 15 (nom. nud.)

Planorbis hardmani (Foord) (sic) Wade, 1924: 29, pl. 1

Planorbis hardmani Wade. Chapman 1937: 61, pl. 6, figs 1, 2

Syrioplanorbis hardmani (Wade). McMichael 1968: 141, pl. 10, figs 6-8

Material: 15 internal casts GSSA M2746; numerous internal casts and moulds in matrix, M3579 (locality 6138 RS 87, 4 km N of "Billa Kalina").

The species was described adequately by McMichael. All specimens show the slight asymmetry with a deeply concave upper surface and shallowly concave lower surface typical of the species. Dimensions of the ten measurable specimens are consistent with those of the types from White Mountain Hills, Western Australia and specimens from south of Herrmansburg in Central Australia:

GSSA Reg. No.	*Diam. (mm)*	*Height (mm)*	*Diam./Height ratio*
M2746(1)	20.0	7.4	2.70:1
M2746(2)	18.0	7.0	2.57:1
M2746(3)	16.4	5.4	3.04:1
M2746(4)	11.4	5.0	2.28:1
M2746(5)	13.7	6.0	2.28:1
M2746(6)	12.0	5.5	2.18:1
M2746(7)	12.4	5.4	2.30:1
M2746(8)	11.9	6.0	1.98:1
M2746(9)	11.4	5.5	2.07:1
M2746(10)	9.6	4.5	2.13:1
Average	13.68	5.77	2.37:1

Type locality: Trig J40, 15 km E of N of "New Ord River", White Mountain Hills, lat. 17°15′37″S, long. 128°57′57″E, LISSADELL 1:250 000 map sheet, Kimberley District, W.A. White Mountain Formation, ?Miocene.

Distribution: The localities cited by McMichael are here reinterpreted from Lloyd (1968), Wells *et al.* (1970) and Playford *et al.* (1975): Western Australia-White Mountain Formation, White Mountain Hills 15 km E of N of "New Ord River", LISSADELL 1:250 000 map sheet; Northern Territory—NT 406, unnamed formation, 6 km W of Running Waters, 42 km S of Herrmansburg, HENBURY 1:250 000 map sheet; NT 409, unnamed formation, 16 km NNE of "Deep Well", 61 km SSE of Alice Springs, RODINGA 1:250 000 map sheet; NT 417, unnamed formation, 16 km NE of Undoolya Gap, 45 km E of Alice Springs, ALICE SPRINGS 1:250 000 map sheet; NT 422, Arltunga Beds, 3.2 km SW of Arltunga airstrip, ALICE SPRINGS 1:250 000 map sheet; NT 423, Arltunga Beds, Arltunga airstrip, ALICE SPRINGS 1:250 000 map sheet; AS 234, unnamed formation, 24 km SE of "Todd River" H.S., ALICE SPRINGS 1:250 000 map sheet; AS 235, unnamed formation, 21 km ESE of "Todd River" H.S., ALICE SPRINGS 1:250 000 map sheet; Queensland — Q9, Horse Creek Formation, 25.6 km SE of "Springvale" H.S., SPRINGVALE 1:250 000 map sheet; BT 169, Brunette Limestone, 45.6 km N of "Rockhampton Downs" H.S., ROBINSON RIVER 1:250 000 map sheet; South Australia — 6138 RS 87, unnamed formation, 4 km N of "Billa Kalina", BILLA KALINA 1:250 000 map sheet.

The genus is recorded from the Late Oligocene of Europe and the Far East, but as living only in Lebanon and Syria. No living representatives are known from Australia.

Habitat: Freshwater.

Syrioplanorbis sp.

FIGS 3v, w

Material: Two internal casts GSSA M3580(1-2), locality 6138 RS 87, 4 km N of "Billa Kalina" H.S.

Description: Sinistral, discoidal, both upper and lower surfaces deeply and fairly broadly umbilicate. Whorls 4½, regularly increasing, laterally somewhat compressed and inclined to be angulate at upper and lower curvature. Sutures deeply impressed. Shell unknown, but cast showing three conspicuous spiral ribs on lateral surface. Aperture more or less symmetrical, moderately arched.

GSSA Reg. No.	*Diam. (mm)*	*Height (mm)*	*Diam./Height ratio*
M3580(1)	12.2	6.3	1.94:1
M3580(2)	10.2	5.0	2.04:1
Average	11.2	5.6	2.0:1

Observations: Two specimens, although not well preserved, appear to differ from *Syrioplanorbis hardmani* in having laterally compressed whorls, which makes the shell relatively higher than *S. hardmani*, with an average diameter: height ratio of 2.0:1 in contrast with 2.37:1 average of ten specimens of *S. hardmani*. It is not known whether the three spiral ribs visible on the internal cast persist as external features.

There are not sufficient specimens, nor are they well enough preserved, to warrant a new specific name.

Distribution: Locality 6138 RS 87, 4 km N of "Billa Kalina", BILLA KALINA 1:250 000 map sheet.

Habitat: Freshwater.

Genus PHYSASTRA Tapparone-Canefri, 1883

Physastra rodingae McMichael

FIG. 3x

Isidora, near *I. pectorosa*, Etheridge in Cameron 1901: 14

Bullinus sp. nov. Chapman 1937: 63

Isodora (sic). Whitehouse 1940:24

Physastra rodingae McMichael, 1968: 146, pl. 11, figs 2-5

Material: Four poorly-preserved casts and moulds, mostly embedded in hard limestone, GSSA M3581 (1-4), locality 6238 RS 87, 4 km N of "Billa Kalina". They appear to be casts and external moulds of juveniles, with about 3 whorls, of the sinistral species which has 4-5 whorls in the adult.

M3581(1), an internal cast freed from the matrix, has dimensions: height 9.0, diameter 5.3 mm, compared with a height 33.0+, diameter 14.5 mm in the largest paratype.

Type locality: NT 407, 12 km NE of "Deep Well", 66 km SSE of Alice Springs, RODINGA 1:250 000 map sheet, unnamed formation.

Distribution: Western Australia-White Mountain Hills, White Mountain Formation, 15 km E of N of "New Ord River", LISSADELL 1:250 000 map sheet; Northern Territory — NT 407, unnamed formation, 12 km NE of "Deep Well", RODINGA 1:250 000 map sheet; NT 424, Waite Formation, 6.4 km S of "Alcoota" H.S., ALCOOTA 1:250 000 map sheet; Queensland—Q11, Carl Creek Limestone, 8 km N of "Riversleigh" H.S., locality 103 on LAWN HILL 1:125 000 map sheet; Q12, Carl Creek Limestone, 1.6 km SE of "Riversleigh" H.S., locality 90 on CAMOOWEAL 1:250 000 map sheet; South Australia — locality 6138 RS 87, unnamed formation, 4 km N of "Billa Kalina" H.S., BILLA KALINA 1:250 000 map sheet. The genus *Physastra* is recorded as living in Indonesia, Australia, New Zealand and New Caledonia.

Habitat: Freshwater.

Observation. McMichael included in the synonymy *Isidora*, near *I. pectorosa* identified by R. Etheridge jr, cited by Cameron (1901) and by Whitehouse (1940) as being abundant, often in crowded masses, in what is now known as the Carl Creek Limestone, which overlies Cambrian limestone near "Riversleigh" from which Lloyd's material also came. This synonymy is accepted in the absence of any material evidence to the contrary.

Order STYLOMMATOPHORA
Superfamily BULIMULACEA
Family BULIMULIDAE
Genus BOTHRIEMBRYON Pilsbry, 1894

Bothriembryon praecursor McMichael

FIGS 3 a-c

Bothriembryon praecursor McMichael, 1968: 149, pl. 11, figs 7-9

Material: 34 internal casts and several external moulds in matrix GSSA M2738 (1-5), M2739 (1-14), M2744 (1-3), M3582 (1-4), all from the type section, Etadunna Formation, dolomitic limestone member 2c, Lake Palankarinna, S. Aust. (locality 6540 RS 59, KOPPERAMANNA 1:250 000 map sheet).

The species is common in dolomitic limestone near the base of the Etadunna Forma-

tion and is here redescribed from internal casts of adult specimens collected from the type section.

Description: Shell not known, but from the appearance of the casts probably fairly thick, size moderate for the genus, elongate-turbiniform, with a moderately high spire and large last whorl; aperture about equal in height to spire; whorls 5, regularly increasing. Protoconch small but fairly high, of two whorls with tip immersed, adult whorls 3, slightly to moderately inflated, suture conspicuous, imbricating. Aperture subovate, outer lip gently arcuate, attached less than ½ way towards adapical suture, parietal lip probably concave, columellar lip nearly vertical, basal lip arcuate; umbilical chink present. Sculpture, as shown on internal cast, of axial folds or growth ridges fairly evenly spaced, about 17 on last whorl; in oblique light, some specimens appear to have 2 or 3 faint and shallow spiral grooves on last whorl, suggesting that there may be some spiral sculpture as well. Dimensions of largest specimen GSSA M2738(1) height 30.5, diameter 17.7 mm, ratio height: diameter 1.72:1, average of 23 specimens height 22.4, diameter 13.5 mm, ratio height: diameter 1.66:1. Two specimens M2738(2) and M2739(1) are conspicuously narrower than average, with dimensions — M2738(2) height 25.1, diameter 14.0 mm, ratio height: diameter 1.80:1, M2739(1) height 28.4, diameter 14.5 mm, ratio height: diameter 1.96:1.

Type locality: Rd 21, 6 km ENE of "Deep Well" H.S., RODINGA 1:250 000 map sheet, unnamed formation.

Distribution: Northern Territory — NT 409, unnamed formation, 16 km NNE of "Deep Well" H.S. 61 km SSE of Alice Springs, RODINGA 1:250 000 map sheet; Rd 21 unnamed formation, 6 km ENE of "Deep Well" H.S., RODINGA 1:250 000 map sheet; South Australia — locality 6540 RS 59, Etadunna Formation, Lake Palankarinna, south of Cooper Creek, KOPPERAMANNA 1:250 000 map sheet.

The pulmonate land snail *Bothriembryon* is restricted to Australia, mainly the south west, but there are representatives in Central Australia and Tasmania. *Bothriembryon barretti* Iredale is commonly found in great numbers under bushes in coastal areas of the Nullarbor Plain, where it survives under dry conditions.

Habitat: It is likely that *B. praecursor* lived in a similar environment.

Observations: McMichael (1968) distinguished between *B. praecursor* and the living *B. barretti*, and also the Tasmanian fossil species *B. gunnii* (Sowerby). The present study supports separating these species. The Pleistocene to Holocene *B. barretti* is a larger and narrower shell; of 173 specimens measured from Point Sinclair, South Australia (Ludbrook 1978), the largest was 39 mm high and 21 mm in diameter, and the average 31.5 mm high, 17.7 mm in diameter, ratio height: diameter 1.78:1.

Bothriembryon gunnii (Sowerby) has been referred to in the literature as follows:

Bulinus gunnii G. B. Sowerby, 1845, in Strzelecki: 298, pl. 19, fig. 6 (not fig. 5)

Bulimus gunnii Sowerby, Etheridge 1878: 177. Johnston 1880: 90. Johnston 1888: 283, pl. 34, fig. 7

Liparus gunni (unjustified emendation) G. B. Sby sp. Harris 1897: 3

The specific name has also been attached to a living Tasmanian species thought by some authors to be identical with it:

Bothriembryon gunnii var. *brachysoma* Pilsbry, 1900: 18, pl. 3, fig. 53

Bothriembryon gunni Sowerby. May 1921: 92; 1923: pl. 42, fig. 7

This is the species referred to in Iredale (1937: 313) and May revised Macpherson (1958, pl. 42, fig. 7) as *Tasmanembryon tasmanicus* Pfeiffer.

Bothriembryon gunnii is now represented solely by the holotype in the British Museum (Natural History), an internal cast embedded in matrix aperture down, so that complete description is impossible. The specimen figured by Johnston (1888) cannot at present be found, and no other specimens are known. Johnston's figure is of an elongate-turbiniform shell with axial ribs and impressed sutures. Although both *Bulinus* and *Bulimus* have been widely used for genera in different families, it may be assumed that in replacing *Bulinus* (a sinistral shell, family Planorbidae) by *Bulimus* (= *Bulimulus*) Johnston implied the position of *Bulimus gunnii* in the Bulimulidae, as did also G. F. Harris in placing the holotype in *Liparus* (a synonym of *Bothriembryon*). Johnston's figure immediately invites comparison of *Bulimus gunnii* with *Tasmanembryon tasmanicum* (Pfeiffer), recorded as common on the east coast of Tasmania, near the sea on trees

and rocks, but the extreme paucity of material is a barrier to confirming the identity of the fossil.

Bulimus gunnii was described with *Helix tasmaniensis* from travertine limestone quarried near Hobart Town (Strzelecki 1845). There is some uncertainty whether this was the quarry visited by Darwin (Banks 1970) or that at Geilston Bay. Neither quarry is now accessible. That in Hobart was identified by Johnston and by Banks as at the western end of Burnett Street. Johnston's figured specimen, occurring also with "*Helix tasmaniensis*" came from the Geilston Travertine which was quarried at Geilston Bay on the northeast side of the River Derwent 3 km north of the Tasman Bridge. Johnston considered this to be the locality visited by Darwin and by Strzelecki. There seems to be no way of recollecting the material or of confirming that the holotype of *Bulimus gunnii* did in fact come from the Burnett Street quarry and not from Geilston Bay, but Geilston Bay seems the more likely locality. In describing the two quarries, McCormick (1847) stated that he found no traces of shells in the Hobart Town quarry, but *Helix* and *Bulimus* were embedded in the upper part of the indurated limestone quarried at Geilston Bay. Ten specimens of two species of "*Helix*" from Geilston Bay were kindly lent by the Geology Department of the University of Tasmania, but no specimens of "*Bulimus*" *gunnii* have been located. One of the specimens of "*Helix*" *tasmaniensis*, partly embedded in matrix, is extremely like Sowerby's holotype.

Direct comparison of *Bothriembryon praecursor* with "*Bulimus*" *gunnii* is therefore impossible at present. Moreover, the stratigraphic position of the limestone containing "*Bulimus*" *gunnii* and "*Helix*" *tasmaniensis* can be stated only as "Tertiary" from present knowledge. Strzelecki considered it to be of Pliocene age. A composite section of the Tertiary sediments at Geilston described by Johnston (1888) was modified by Tedford *et al.* (1975). Johnston recorded marsupial bones from yellow and brown mottled calcareous clay, which, according to Tedford *et al.*, is interbedded with the travertine. They compared a diprotodontid from the Geilston Travertine with *Ngapakaldia* from the Etadunna Formation, of Middle Miocene age. An apparent age of 22.4± 0.5 Ma was obtained for basalt overlying the travertine. A sample of carbonaceous sediments collected below basalt at Geilston Bay on the west side of the golf links was sent by the Tasmanian Museum to W. K. Harris, who has informed me verbally that "the age of the microflora is ?Pliocene-Pleistocene; it is not related to mid-Tertiary microfloras widespread in Tasmania".

It can only be said that dating of material from the sequence at Geilston Bay is confused, and any correlation with the Etadunna Formation based on molluscs out of the question. Neither "*Bulimus*" *gunnii* nor "*Helix*" *tasmaniensis* can be compared with known molluscs from the Etadunna Formation.

Superfamily HELICACEA
Family CAMAENIDAE
Genus MERACOMELON Iredale, 1937

Meracomelon lloydi McMichael

FIGS 3 f-l

Meracomelon lloydi McMichael, 1968: 151, pl. 11, figs 10-14

Material: Nine internal casts GSSA M2740-3, M3582 (1-2), one external mould.

The species was described by McMichael from internal casts and so far the Etadunna Formation has yielded only external moulds and internal casts. Etadunna specimens are generally smaller and higher than the holotype and paratypes from the Northern Territory and Queensland. They vary considerably in their relative height:

GSSA Reg. No.	*Diam. (mm)*	*Height (mm)*	*Diam./Height ratio*
M2740	22.0	17.8	1.24:1
M2741(1)	15.5	10.0	1.55:1
M2741(2)	12.0	6.4	1.87:1
M2742(1)	14.0	10.4	1.34:1
M2742(2)	13.5	8.6	1.57:1
M2742(3)	11.9	7.7	1.54:1
M2743	12.0	9.0	1.33:1
M3582(1)	13.5	8.7	1.55:1
M3582	13.3	7.0	1.90:1
Average of 9 specimens	14.2	9.5	1.49:1
Average of holotype and 5 paratypes	18.9	14.0	1.35:1

Type locality: NT 409, 16 km NNE of "Deep Well": 61 km SSE of Alice Springs, RODINGA 1:250 000 map sheet, unnamed formation.

Distribution: Northern Territory — NT 409, 16 km NNE of "Deep Well", NT 407, 12 km NE of "Deep Well", NT 408, 1.6 km N of NT 407, and Rd 21, 6 km ENE of "Deep Well", all unnamed formation, RODINGA 1:250 000 map sheet; South Australia — locality 6450 RS 59, Etadunna Formation, Lake Palan-

katinna, south of Cooper Creek, KOPPERAMANNA 1:250 000 map sheet.

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TRANSACTIONS OF THE
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NOTES ON THE MAMMALS AND REPTILES OF PEARSON, DOROTHEE AND GREENLY ISLANDS, SOUTH AUSTRALIA

BY A. C. ROBINSON

Summary

Collections and observations of the mammals and reptiles of Pearson, Dorothee and Greenly Islands off the west coast of Eyre Peninsula were made in November 1975 and 1976. Southern Bush Rats on Pearson Island are smaller, breed earlier, and occur at a lower population density than on Greenly Island. The difference in population density may be explained by the different stages in the reproductive cycle on the two islands in November. Population estimates of the Pearson Island Rock Wallaby and the introduced population of Tammar Wallabies on Greenly Island are given. An annotated list of all reptiles recorded from the islands is given.

NOTES ON THE MAMMALS AND REPTILES OF PEARSON, DOROTHEE AND GREENLY ISLANDS, SOUTH AUSTRALIA

by A. C. Robinson*

Summary

Robinson, A. C. (1980) Notes on the Mammals and reptiles of Pearson, Dorothee and Greenly Islands, South Australia. *Trans. R. Soc. S. Aust.* **104**(5), 93-99, 28 November, 1980.

Collections and observations of the mammals and reptiles of Pearson, Dorothee and Greenly Islands off the west coast of Eyre Peninsula were made in November 1975 and 1976. Southern Bush Rats on Pearson Island are smaller, breed earlier and occur at a lower population density than on Greenly Island. The difference in population density may be explained by the different stages in the reproductive cycle on the two islands in November. Population estimates of the Pearson Island Rock Wallaby and the introduced population of Tammar Wallabies on Greenly Island are given. An annotated list of all reptiles recorded from the islands is given.

Introduction

In November 1976, a biological survey of Pearson Island and Dorothee Island (Investigator Group) and Greenly Island was undertaken by A. C. Robinson, T. J. Fatchen, A. Spiers and J. B. Cox (South Australian National Parks and Wildlife Service) and S. A. Parker and W. Zeidler (South Australian Museum).

Pearson Island is located at 34°4'S, 134° 17'E, Dorothee Island at 34°0'S, 134°15'E and Greenly Island at 34°39'S, 134°45'E. Four days and nights were spent on Pearson Island, a day and a night on Dorothee Island and four days and nights on Greenly Island. In November 1975 a two day trip to Pearson Island was made and some small mammal trapping and observation of the rock wallaby population was carried out.

This paper presents observations made on the mammals and reptiles of these islands. The birds are discussed in Parker & Cox (1978) while the vegetation will be examined in Fatchen (in prep.). Previous observations (summarised here) are available from expeditions to Pearson Island in 1914, 1922, 1923 (Proctor 1923, Wood-Jones 1922, 1923, 1924), 1960, 1968, 1969 (Thomas & Delroy 1971) 1969 (Smyth 1971), 1973 (Gepp 1973[1]), 1974 (Schmitt 1975) and Field Naturalists' Society Mammal Club unpublished observation; from Dorothee Island in 1969 (Smyth 1971); and from Greenly Island in 1947 (Finlayson 1948a, b; Mitchell & Behrndt 1949).

The three islands are all essentially granite based islands with very little of their original limestone capping remaining, the geomorphology of Pearson and Dorothee Islands having been described by Twidale (1971). Mitchell & Behrndt (1949) gave a general description of Greenly Island, while the geology of the Greenly Island basement rock is described by Webb & Thomson (1977).

The vegetation of the three islands is similar, that of Pearson and Dorothee Islands being described by Osborn (1923), Specht (1969) and Symon (1971) while that of Greenly was described by Finlayson (1948, a, b), Mitchell & Behrndt (1949) and Cleland (1950).

In addition to the general biological survey carried out on the islands an attempt was made to determine the effect of fire on the flora and fauna. An extensive area on the southern part of the main Pearson Island was burnt in a fire which is believed to have started from a lightning strike on the island peak in early April, 1975 (D. Steen pers. comm.). This fire must have been extremely hot, and total destruction of the above ground parts of the vegetation has occurred over large areas. The extent of the fire is shown in Fig. 1.

On Greenly Island a number of fires were lit by tuna fishermen on 6 February, 1974. The areas burnt are shown on Fig. 2 from unpublished records of the fire, prepared by members of the N.P.&W.S. who visited the island on 24 February, 1974.

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[1] Gepp, B. (1973) The Social Organisation of the Pearson Island Rock Wallaby (*Petrogale penicillata pearsoni*). B.Sc. Hons. thesis. Zoology Department, University of Adelaide.

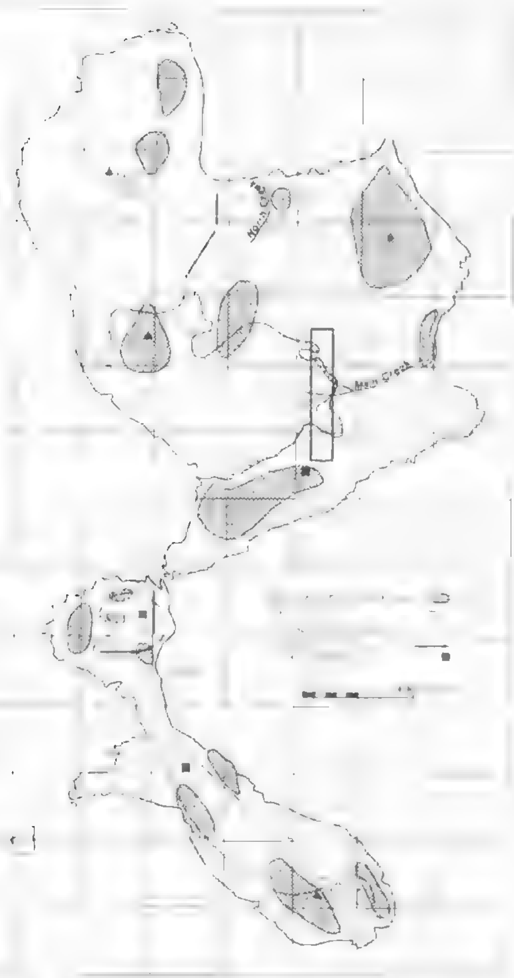

Fig. 1. Pearson Island showing location of trapping areas, transect counts and wallaby populations.

Methods

An arbitrary grid system with 250 m grid intervals was established over the three islands to be sampled (Figs 1, 2). Collecting and observation efforts sampled as many of the grid intersections as possible to obtain good coverage of the range of habitats on the islands. Line transects at night using a spotlight were walked on both central and south Pearson, and during the day on Greenly Island to try and estimate the wallaby populations. Small mammals were sampled by systematic trapping using Elliot and Sherman aluminium box traps set either on a grid pattern or in lines. All *Rattus fuscipes* trapped were weighed and individually marked by toe clipping. The reproductive condition noted by recording if testes were descended or undescended in males and if vaginae were perforate or imperforate and if nipples were enlarged by suckling in females.

(a) *Pearson Island:* On 2 November, 1975, two traplines were set above the northern bay (Fig. 1). Each had 10 sites at 20 m intervals with three traps per site. On 24–25 November, 1976, two traplines were set on the centre section (Fig. 1). Each had 12 sites at 20 m intervals with two traps per site. At the same time a grid was established on the main island with 80 sites at 25 m intervals and two traps per site. This grid was positioned to sample as wide a range of vegetation as possible from the low *Atriplex* shrubland near the coast through the closed *Melaleuca halmaturorum* scrub along the creek and into the low *Casuarina* woodland on the slopes of the island peak. In addition the grid sampled as equally as possible areas burnt in the 1975 fire and unburnt areas. There were 34 sites in the burnt area and 46 unburnt sites.

(b) *Dorothee Island*: On 27 November, 1976, two traplines were set in a WNW and SE direction from the conservation park sign on the central eastern shore. Each had 20 sites at 20 m intervals with two traps per site.

(c) *Greenly Island*: On 29–30 November, 1976, a trapline was set above the anchorage (Fig. 2.). It had 12 sites at 20 m intervals with two traps per site, and a grid was established on the northern slopes of the main island (Fig. 3) with 48 sites at 25 m intervals and two traps per site. This grid was positioned to sample as wide a range of vegetation as possible from the *Poa* tussock grassland on the lower slopes to the low *Casuarina* woodland on the upper parts of the island. The grid sampled areas of grassland burnt in the 1974 fires. It was not possible to distinguish boundaries between burnt and and unburnt sites due to the degree of regeneration.

All species of mammals and reptiles recorded from the islands are discussed. South Australian Museum registration numbers are recorded of specimens collected.

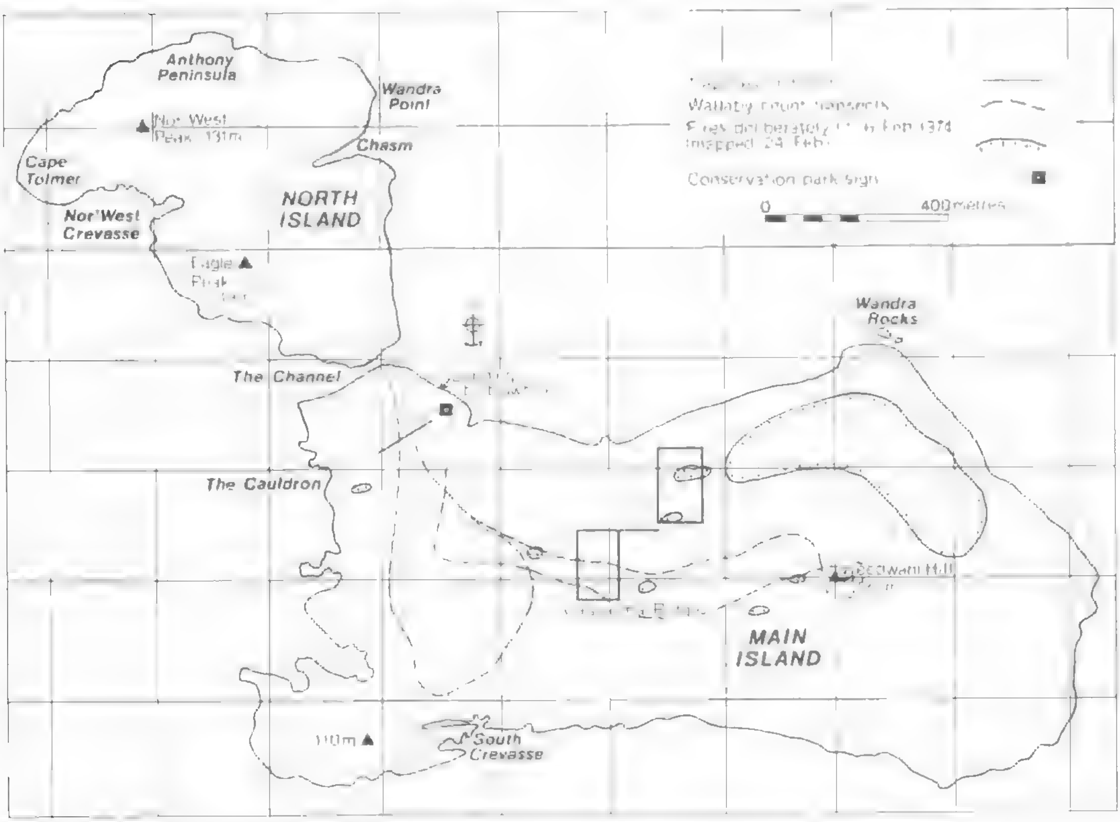

Figure 2. Greenly Island showing location of trapping areas and wallaby count transects.

Results

MAMMALS

Family MACROPODIDAE

Petrogale lateralis Gould. Pearson Island Rock Wallaby. This species was collected in 1920 by Wood Jones from Pearson Island and Thomas (1922) described it as a new species (*P. pearsoni*). Since then there has been considerable confusion about its relationship with other rock wallabies and this is discussed by Thomas & Delroy (1971). Recent chromosome and electrophoretic studies (G. Sharman pers. comm.), place the Pearson Island animals with western and central Australian populations of *P. lateralis* (Poole, 1979). *P. lateralis* also occurred in the far north-west of the South Australian mainland but may now be extinct. Early visitors to Pearson Island mentioned that the rock wallabies occurred only on the northern section (Wood Jones 1923). This section is separated from the central and southern section by a sand spit that dries at low tide. The 1960 expedition also noted the absence of wallabies on the middle and south sections of the island and they found no trace of skeletons or of occupation of several caves on the southern section. On the 1960 expedition several wallabies were caught on the northern section and transferred to a camp on the middle section. Four females, one male and one animal of unknown sex escaped. It appears certain that the present rock wallaby population on the middle and southern sections of Pearson Island is descended from these six escapees.

Thomas & Delroy (1971) estimated that there were 50–150 wallabies on the middle and southern sections in 1968 and showed that this 1960–1968 population increase was theoretically possible from the original six animals. In 1976, transect counts of the middle section in the evening (24 November) and at night by spotlight (25 November) revealed 64 and 40 individuals respectively, while a spotlight transect on the southern section (25 November) revealed 92 individuals. Thus the total population of the middle and southern sections is at least 150. The distribution of this population is shown in Fig. 1.

It is much more difficult to estimate the wallaby population on the northern section of Pearson Island. The population is fragmented (Fig. 1) being confined to areas with suitable rock crevices and caves and the dense vegetation makes sighting difficult. Thomas & Delroy (1971) provide two estimates for the northern section: 1960—500 to 600 and 1968 in excess of 500. In November 1975, the author walked over the whole of the northern section and counted 132 individuals: this was undoubtedly too low and the total population is probably twice this size between 250 and 300. No estimates of the population on the northern section were attemped in 1976.

The diet of the wallabies was observed to include *Lepidium foliosum, Atriplex cinerea, A. paludosa, Rhagodia baccata, Enchylaena tomentosa, Olearia ramulosa, Carpobrotus rossii* and *Disphyma australe*. On the northern section, even around the major colonies of wallabies there was little evidence of grazing of the vegetation. On the middle and southern sections however, large areas of vegetation were obviously very heavily grazed. This was particularly the case with *E. tomentosa*, while *D. australe* and *A. paludosa* were also being affected.

Macropus eugenii (Desmarest) Tammar. SAM, M9786. An unknown number of Tammars were introduced to Greenly Island from Kangaroo Island in about 1905 to act as an emergency food supply for possible castaways (Mitchell & Behrndt 1949). They now occur on both the main central and small south-western section of the island but are apparently absent from the northern section. They spend the daytime in the dense teatree thickets on the south side of the main ridge of the island and also occupy some of the gullies on the northern slopes of the island. They are extremely difficult to observe and the two transect counts (Fig. 2) resulted in the sighting of four and 14 individuals. It is probable that the total population is about 50 individuals.

The stability of the Tammar population on Greenly Island is not known, but a comparison of the vegetation of the main island with the northern section where wallabies are absent reveals that they have had a substantial impact on the island vegetation. There has been significant reductions in both species diversity and ground cover and it appears that the present vegetation of the main section of Greenly Island is a direct result of severe over-grazing by the introduced Tammar population over the last 70 years.

Family Muridae

Rattus fuscipes (Waterhouse). Southern Bush Rat SAM M9787–91. This species is common on both Greenly and Pearson Islands but appears absent from Dorothee Island. The populations on both islands were probably derived from a population distributed across most of Southern Australia during the last ice age when both the islands were connected to the mainland. Schmitt (1978) and Schmitt & White (1979) have estimated that Pearson and Greenly Islands have been isolated from the mainland for 14 000 years. They have emphasised the importance of genetic drift in producing the differences between the island populations that they studied. The grid trapping carried out on this expedition provides an opportunity to obtain additional comparative data. Accordingly, the two islands are discussed separately below.

Pearson Island

Schmitt (1975) has demonstrated that significant genetic differences occur between the Bush Rat populations on the northern and southern sections of the island. The grid was located on the northern section (Fig. 1) and the following discussion refers to this population only.

(a) *Population density*: Twenty-six individuals were captured on the 50 000 m² of the grid. Therefore, ignoring boundary effects, the overall density was 5.2 rats/ha.

As approximately half the grid was in the area burnt by the 1975 fire it is appropriate to examine the differences in population density in the burnt and unburnt areas: Burnt sites 3.8 rats/ha; unburnt sites 6.3 rats/ha.

(b) *Sex ratio* 13 ♂♂ : 13 ♀♀

(c) *Body weight*: ♂♂ 40.4 g (30–55, n = 13); ♀♀ 49.1 g (30–70, n = 13)

(d) *Reproductive status*: All the males captured were sub-adult with undescended testes. Five of the females still had imperforate vaginas while those with perforate vaginae showed no indication that their nipples had been suckled. This suggests that there had been a spring breeding season with a very high mortality of

both male and female adults to result in this largely immature population in November.

Greenly Island

Although the part of the island covered by the trapping grid had been burnt in 1974, it was impossible to distinguish burnt and unburnt areas, so the whole grid was treated as a single area.

(a) *Population density:* Thirty-seven individuals were captured on the 30 000 m^2 of the grid. Therefore, ignoring boundary effects the overall density was 13.3 rats/ha.

(b) *Sex ratio:* 18 ♂♂ : 19 ♀♀

(c) *Body weight:* ♂♂ 83.8 g (35–130, n = 18); ♀♀ 70.7 g (40–100, n = 19)

(d) *Reproductive status:* Seven of the males were sub-adult but although all the remaining males were of adult weight, only two still had descended testes. Of the females three still had imperforate vaginae while four of those with perforate vaginae had developed nipples, indicating a recent cessation of the feeding of the young. This suggests that the breeding season had just ended and that at this stage in the population cycle there had been a high survival of both males and females from the parental generation.

A comparison of the Bush Rat populations of Pearson and Greenly Island indicates that the Greenly Island population occurs at a significantly higher density, even considering the population density on the unburnt portion of the Pearson Island grid. In addition the Greenly Island animals were much heavier and larger than the Pearson Island animals. Finally it appears that at least in 1976 there was a spring breeding season with a possibility of breeding continuing into early November on Greenly Island.

Additional comparative data on Bush Rat population densities on South Australian offshore islands are shown in Table 1. The figures are given as trapping percentages and with the exception of this present study are based on trap lines rather than grid trapping so no absolute densities can be obtained.

The differences in population densities between Pearson and Greenly Islands shown by the grid studies are also apparent in the line trapping. Schmitt's line trapping figures obtained in February and March however showed similar trapping success rates on both islands and it is possible that the differences demonstrated in the grid study in November may be due simply to greater survival of adults from the breeding season on Greenly Island than on Pearson Island. The high trapping success on other South Australian offshore islands indicates that high population densities of Bush Rats are a feature common to all of these islands.

Family OTARIIDAE

Neophoca cinerea (Peron & Lesueur) Australian Sealion. This species was present on each of the islands visited.

Pearson Island: 20–30 individuals, 4–6 mature bulls, the major concentration was on the beach on the centre section of the island

TABLE 1. *Comparison of results of trapping studies of* Rattus fuscipes *on South Australian offshore islands*

Island	Month	Type of Trapping	Trapping Success %	Source
North Pearson I.	Nov	line	5	This Study
North Pearson I.	Feb	line	40	Schmitt (pers. comm.)
North Pearson I.	Nov	grid	8	This Study
South Pearson I.	Feb	line	27	Schmitt (pers. comm.)
South Pearson I.	Nov	line	19	This Study
Greenly I.	Mar	line	22	Schmitt (pers. comm.)
Greenly I.	Nov	line	30	This Study
Greenly I.	Nov	grid	21	This Study
Waldegrave I.	Feb	line	68	Schmitt (pers. comm.)
Williams I.	Apr	line	82	Schmitt (pers. comm.)
North Gambier I.	Apr	line	52	Schmitt (pers. comm.)
Dog I.	Jun	line	73	Schmitt (pers. comm.)
Goat I.	Jun	line	62	Schmitt (pers. comm.)

Dorothee Island: 30 individuals, 7 mature bulls, the major concentration was on a sloping rock shelf on the north side of the central crevasse and on the saltbush covered slopes around a wallowing area.

Greenly Island: 30 individuals, 4 mature bulls, the major concentration was on a sloping granite shelf on the north face of the main island.

On all islands there were immature animals 1.5–2 m long associated with females, and some were observed to be suckling although they were often abandoned by their mothers on the higher parts of the island.

Arctocephalus forsteri (Lesson). New Zealand Fur Seal. This species was found only on Dorothee and Greenly Islands.

Dorothee Island: 16 individuals, 1 mature bull, concentrated in cracks and holes in the rock around the central crevasse.

Greenly Island: 40 individuals, 4 mature bulls with the major concentration on the sloping granite shelf on the north face of the main island near the blowhole. There was another small group in the south crevasse.

On both islands there were some immature animals 1–1.5 m long still associated with their mothers.

REPTILES

Family Gekkonidae

Phyllodactylus marmoratus (Gray). Marbled Gecko SAM, R15800A–D, R15802, A, B, R15807 A–D, R15809, R15815 A, B. Previously reported by Proctor (1923), Mitchell & Behrndt (1949) and Smyth (1971). Found on all three islands. Common in areas of limestone capping but also under exfoliating slabs of granite. Two clutches of eggs found on Pearson Island under a large slab of granite contained 14 and six eggs respectively. As this species lays only two eggs at a time it would appear that communal laying occurred at favoured sites.

Underwoodisaurus millii (Borg). Although not recorded in his paper, Smyth deposited specimens of this species from Pearson Island in the S.A. Museum. (R10237 A–B).

Family Pygopodidae

Aprasia striolata (Lutken). Although not recorded in his paper, Smyth deposited a specimen of this species from Pearson Island in the S.A. Museum. (R10232).

Family Agamidae

Amphibolurus fionni Proctor. Peninsula Dragon SAM R15801, R15803–6, R15820 A–B. Only found on Pearson and Dorothee Islands and previously reported by Proctor (1923) and Smyth (1971). Closely associated with granite out-crops. Further details of its offshore island distribution are discussed by Houston (1974).

Family Scincidae

Egernia multiscutata Mitchell & Behrndt SAM R15182 A–B, R15813 A–B, R15814. Recorded only from Greenly Island (Mitchell & Behrndt 1949). It was recorded only from Greenly Island on this occasion and found to be abundant in the *Casuarina* woodland, living in burrows beneath fallen logs and rocks. Also trapped in the *Poa* grassland but appeared much less common in this habitat.

Hemiergis peronii (Fitzinger) SAM R15808 A–C, R15810 A–B, R15811 A–B, R15816 A, B. Found on all three islands, previously reported by Proctor (1923), Mitchell & Behrndt (1949) and Smyth (1971). It was common in loose soil and accumulated organic matter at the base of plants and under rocks and fallen timber.

Leiolopisma entrecasteauxii (Duméril & Bibron). A single specimen was collected from Pearson Island in 1923 (Proctor 1923). It has not been collected there since.

Lerista frosti (Zietz). Not found by the present expedition but reported to be common on Pearson and Dorothee Island (Smyth 1971), while a single specimen (recorded as *Rhodona tetradactyla*) was taken from the peak of the main section of Greenly Island (Mitchell & Behrndt 1949).

Lerista picturata (Fry). Although not recorded in his paper, Smyth deposited a specimen of this species from Pearson Island in the S.A. Museum (R10235).

Menetia greyii (Gray). Recorded on Greenly Island by Mitchell & Behrndt (1949) but not seen or collected in 1976.

Morethia obscura (Storr). SAM R15819. Small fast moving skinks probably of this species were seen on Greenly Island and one specimen was collected from Pearson Island. It has been recorded from Pearson (Smyth 1971) and Greenly Islands (Mitchell & Behrndt 1949), as *M. lineoocellata*, but not from Dorothee Island.

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CATALOGUE OF PLEISTOCENE VERTEBRATE FOSSILS AND SITES IN SOUTH AUSTRALIA

BY D. L. G. WILLIAMS

Summary

The Pleistocene vertebrate fossil sites of South Australia are listed, summarising fossil assemblages and depositional environments. References to the literature are provided. A list of SAM specimens is available.

CATALOGUE OF PLEISTOCENE VERTEBRATE FOSSILS AND SITES IN SOUTH AUSTRALIA

by D. L. G. WILLIAMS*

Summary

WILLIAMS, D. L. G. (1980) Catalogue of Pleistocene vertebrate fossils and sites in South Australia. *Trans. R. Soc. S. Aust.* **104**(5), 101-115, 28 November, 1980.

The Pleistocene vertebrate fossil sites of South Australia are listed, summarising fossil assemblages and depositional environments. References to the literature are provided. A list of SAM specimens is available.

Introduction

The Catalogue originated as part of a Ph.D. research project involving Late Pleistocene fossil vertebrates and palaeoclimates in the Flinders Ranges area of South Australia. Information from museum records, published work and the author's own field observations is summarised but discussion is kept to a minimum.

Sites are listed in numerical order, based on geographic proximity. An alphabetical index is provided. Names conform as far as possible to the Australian 1:250 000 Gazetteer (Division of National Mapping, Dept of Minerals & Energy 1975). Referred map sheets, e.g. ORROROO, are in the 1:250 000 series. Cave sites are numbered according to Lewis (1976). Sites in the L. Eyre region are distinguished by numbers (e.g. V5772) assigned by the UCMP. A key to all sites is given in Figure 1.

Institutions housing relevant fossil collections are abbreviated: **SAM** — South Australian Museum, **FUSA**—Flinders University of South Australia, **AUGM**—Adelaide University Geology Museum, **SADME** — South Australian Department of Mines and Energy, **NMV**—National Museum of Victoria, **AM**—Australian Museum, **AMNH**—American Museum of Natural History, **UCMP**—University of California Museum of Paleontology, **SI**—Smithsonian Institution, **BMNH**—British Museum (Natural History), **HM**—Hunterian Museum.

In presenting lists of previously published assemblages, the identifications of other authors are quoted directly, although in some cases taxa do not conform to current usage. Published lists are available for sites 1–3, 16, 47, 48, 54, 55, 63, 64i, 66e. Other assemblages have been mentioned in the literature, but were not necessarily identified formally. These data refer to sites 9, 18, 20, 31, 40, 42, 52, 53, 56, 57, 60. The majority of sites, however, are unstudied. Much of the material has been examined by the author, but not in detail. Identifications rely on museum catalogues and collections. Sites involved are 4–8, 10–15, 21–24, 28, 32, 38, 41, 43, 45, 49–51, 57–59, 61, 62, 64, 66–68. The remainder of the sites fall into two categories. The first includes sites under detailed study by the author: 17, 19, 22, 25–27, 29, 30, 33–37, 39, 40. The second includes assemblages personally communicated by other workers: sites 44, 46, 64i. Specimen numbers are not given here, but a list of SAM catalogue numbers, arranged geographically, is available from the author.

The Catalogue should not be used directly as a source of biogeographic information. Until more is known of the ages of the deposits, and the bias affecting the fossil assemblages, such a use would be premature. The Catalogue is intended as a summary, which will facilitate access to museum collections, and draw attention to deposits which may have been overlooked.

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Catalogue

1. **WEEKES CAVE** (N 15) 31°31'S, 129°55'E (COOMPANA).
Nullarbor Plain, near Koonalda Station. **SAM**.
BIRDS: Threskiornithidae; *Platibus flavipes*.
Accipitridae; *Accipiter fasciatus*.
Falconidae; *Falco cenchroides*.
Turnicidae; *Turnix* sp.
Sylviidae; *Cinclorhamphus cruralis*, *C. mathewsi*.
Estrilidae; *Poephila guttata*.
Artamidae; *Artamus leucorhynchus*.
van Tets (1974b).

2. **CALCA** 33°02'S, 134°22'E (ELLISTON)
SE of Streaky Bay, near Baird Bay. Red sandy sediments 5–7 m deep in well excavation. **SAM**.
MARSUPIALS: Macropodidae; *Sthenurus* sp., *Procoptodon goliah*.
Merrilees & Ride (1965).

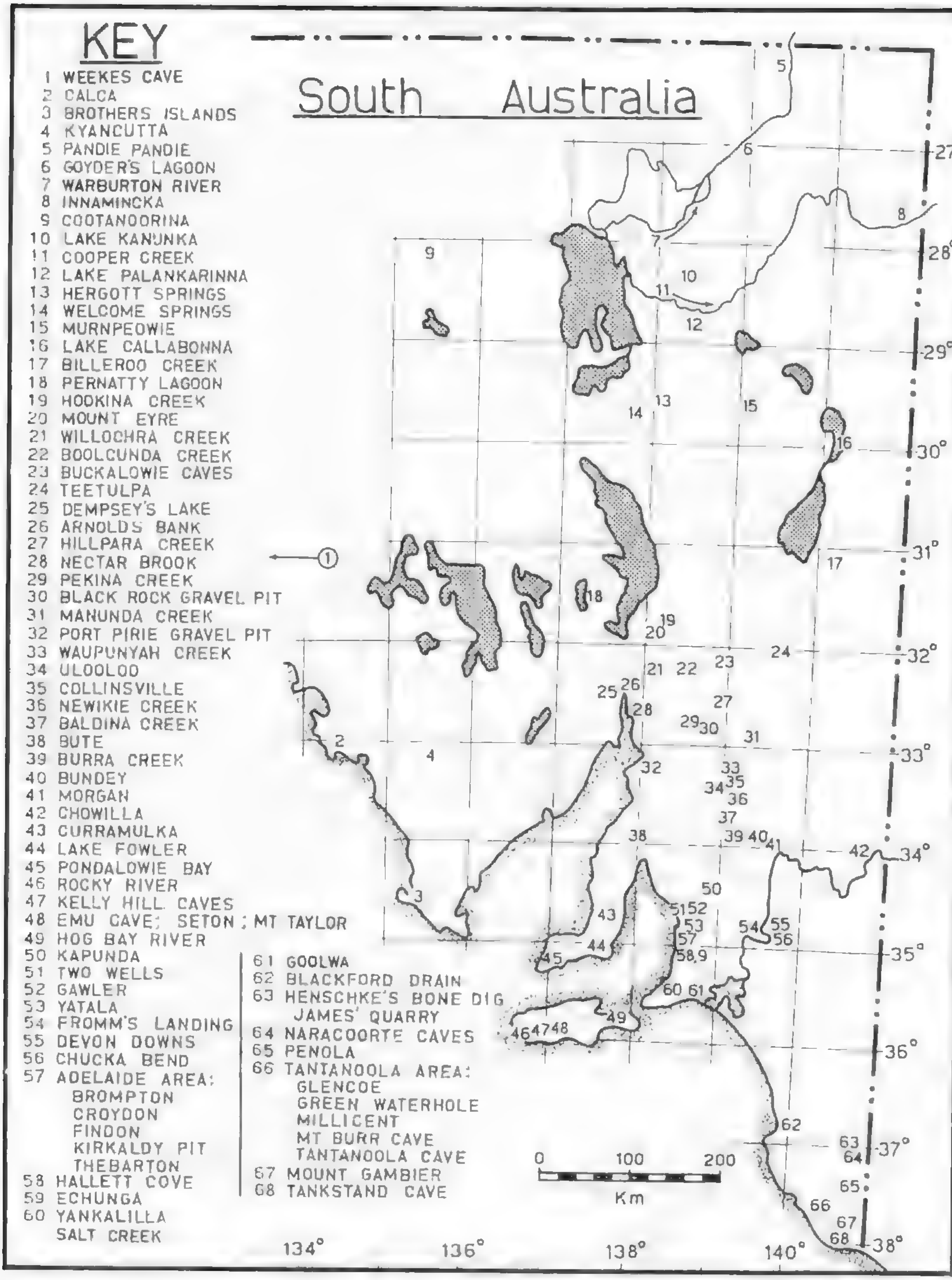

Fig. 1. Distribution of Pleistocene vertebrate sites in South Australia.

3. **BROTHERS ISLANDS** 34°35'S, 135°20'E (LINCOLN).
Western end of western island, in Coffin Bay. Eroded cave mined for guano for a few years from 1902. **SAM.**
MARSUPIALS: Macropodidae; *Macropus* sp, *Sthenurus* cf. *maddocki.*
EUTHERIANS: Otariidae; *Arctocephalus* sp.
BIRDS: Dromornithidae; *Genyornis newtoni.*
Unidentified small bird bones.
Jack (1919), Johns (1966), Rich (1979).

4. **KYANCUTTA** 33°08'S, 135°33'E (KIMBA).
Central Eyre Peninsula. Bone fragments and teeth labelled "Kyancutta N.S.W.". Specimens possibly collected in N.S.W., and acquired from the defunct Kyancutta Museum. (T. H. Rich pers. comm. 1979). **NMV.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.

5. **PANDIE PANDIE** 26°08'S, 139°23'E (PANDIE PANDIE).
Far NE of South Australia. Incisor and bone fragments. **SAM.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.

6. **GOYDER'S LAGOON** 27°01'S, 138°54'E (GASON).
Diamantina River. Bone fragments. **SAM.**
MARSUPIALS: Diprotodontidae; *?Diprotodon* sp.

7. **WARBURTON RIVER.** A number of sites between L. Eyre and the Birdsville Track. Fossils from Katipiri Sands equivalent. **SAM, HM, UCMP.** Note: Lists of fossil assemblages derived from **UCMP** collection.

a. **Cassidy Locality** (V5539) 27°48'S, 138°12'E (GASON).
MARSUPIALS: Vombatidae; *Phascolonus* cf. *gigas.*
Diprotodontidae; *Diprotodon* sp.
Macropodidae; *?Onychogalea* sp., *Protemnodon* cf. *brehus, Sthenurus* cf. *occidentalis.*
BIRDS: Dromornithidae.
REPTILES: Varanidae; *Megalania* sp.

b. **New Kalamurina** (V72058) 27°44'S, 138°15'E (GASON).
MARSUPIALS: Vombatidae; *Phascolonus* cf. *gigas.*
Diprotodontidae; *Diprotodon* cf. *optatum.*
Macropodidae; *Macropus* sp., *Sthenurus* sp., *Procoptodon* cf. *rapha.*
REPTILES: Varanidae; *Megalania* sp.
Crocodilians
FISH: Unidentified material.

c. **Marcus Locality** (V5569) 27°53'S, 137°59'E (NOOLYEANA).
MARSUPIALS: Dasyuridae; *Sarcophilus* cf. *laniarius*
Diprotodontidae; *?Zygomaturus* sp.
Macropodidae.

d. **Green Bluff Locality** (V5775) 27°53'S, 137°56'E (NOOLYEANA).
MARSUPIALS: Vombatidae; *Phascolonus* cf. *gigas.*
Diprotodontidae; *Diprotodon* cf. *optatum, Zygomaturus* sp.
Macropodidae; *Macropus* sp., *Osphranter* sp., *?Wallabia* sp., *Protemnodon* cf. *anak, Sthenurus* sp., *S.* cf. *orientalis, S.* cf. *pales, S.* cf. *tindalei, Procoptodon* cf. *goliah, P.* cf. *rapha.*
BIRDS: Anhingidae; *Anhinga* sp.
Phalacrocoracidae; *Phalacrocorax carbo.*
REPTILES: Varanidae; *Megalania* sp.
Chelonians and Crocodilians.
FISH: Siluriformes and Dipnoi.

e. **Lookout Locality** (V5776) 27°52'S, 137°55'E (NOOLYEANA).
MARSUPIALS: Vombatidae; *Phascolonus* cf. *gigas.*
Diprotodontidae; *Diprotodon* cf. *optatum*
Macropodidae; *Macropus* sp., *Sthenurus* cf. *andersoni, Procoptodon* cf. *rapha.*
BIRDS: Phalacrocoracidae; *Phalacrocorax varius.*
REPTILES: ?Varanidae.
Chelonians and Crocodilians.
FISH: Siluriformes and Dipnoi.

f. **Punkrakadarinna Soakage** (V5777) 27°47'S, 137°49'E (NOOLYEANA).
MARSUPIALS: Diprotodontidae; *Diprotodon* cf. *optatum.*
Tate (1886), Zietz (1899), Etheridge (1894), Stirling (1913), Howchin (1930), Stirton *et al.* (1961), Pledge (1973), Hecht (1975), R. H. Tedford (pers. comm. 1980).

8. **INNAMINCKA** 27°45'S, 140°44'E (INNAMINCKA).
NE of South Australia. **SAM.**
REPTILES: Varanidae; *Megalania prisca.*

9. **COOTANOORINA** 28°10'S, 135°18'E (WARRINA).
NW of L. Eyre, near The Peake. Jaw found at depth of "26 to 30 feet" in well excavation, "at the head of one of the mound springs" (Chandler 1882).
MARSUPIALS: Diprotodontidae; *Diprotodon australis.*
Chandler (1882), Brown (1894), Howchin (1930).

10a. **LAKE KANUNKA** 28°23'S, 138°18'E (KOPPERAMANNA)
East of L. Eyre. Kanunka Fauna in Katipiri channel sands and floodplain deposits. ?Early Pleistocene. **SAM, NMV, AMNH, SI, UCMP** V5772 and V5773.
MARSUPIALS: Dasyuridae.
Vombatidae; *Phascolonus* sp., cf. *Vombatus* or *Lasiorhinus* sp.
Thylacoleonidae.
Diprotodontidae; cf. *Diprotodon* sp., cf. *Zygomaturus* sp.

Macropodidae; *Bettongia* sp., *Macropus* spp., *Osphranter* sp., *Lagorchestes* sp., cf. *Wallabia* sp., cf. *Prionotemnus* sp., *Troposodon kentii*, *Protemnodon* sp., *Sthenurus* sp.
EUTHERIANS: Muridae.
BIRDS: Dromornithidae; *Genyornis* sp.
Phalacrocoracidae; *Phalacrocorax* spp.
Anatidae; *Anas* sp., *Cygnus* sp.
REPTILES: Varanidae.
Unidentified Chelonians and Crocodilians.
FISH: Ceratodontidae; *Epiceratodus* sp.
CRUSTACEANS: Decapods.
Debney (1882), Tate (1886), Stirton *et al.* (1961), R. H. Tedford (pers. comm. 1980).

10b. **MURRAPATERINNA** 28°26'S, 138°31'E (KOPPERAMANNA).
Between L. Kanunka and Mulka. Fossils from bore 15 m deep, 28 Aug. 1921. **SAM** Director, Waite, identified Crocodilian, Lungfish, and Macropodid teeth and bones.
Also, **NMV** collection Nov. 1929, "Marree via Mulka per Sir Colin MacKenzie" from George Aiston:
MARSUPIALS: Diprotodontidae; *Diprotodon* sp., ?*Zygomaturus* sp.
Macropodidae; *Macropus* sp., *Protemnodon* sp.

11. **COOPER CREEK.** A number of sites between L. Eyre and the Birdsville Track. Katipiri Waterhole is the type locality for the Katipiri Sands (?Plio-Pleistocene) from which fossil vertebrates are eroded by the creek. **SAM, NMV, AMNH, UCMP, BMNH, HM.** Note: Lists of fossil assemblages are derived from the UCMP collection.

a. **Cannatalkaninna** (V5377) 28°40'S, 138°26'E (KOPPERAMANNA).
East Cooper crossing. ?Sub-Recent.
MARSUPIALS: Dasyuridae.
Muridae; *Rattus* sp., *Notomys* sp.

b. **Unkumilka Waterhole** (V5378) 28°41'S, 138°19'E (KOPPERAMANNA).
MARSUPIALS: Diprotodontidae; *Diprotodon* sp., ?*Zygomaturus* sp.

c. **V5379** 28°39'S, 138°18'E (KOPPERAMANNA).
SE of White Crossing.
MARSUPIALS: Thylacoleonidae; ?*Thylacoleo* sp.
Diprotodontidae; *Diprotodon* sp.
Macropodidae; ?*Procoptodon* sp.
REPTILES: Varanidae; *Megalania* sp.

d. **V5380** 28°37'S, 138°14'E (KOPPERAMANNA).
MARSUPIALS: Macropodidae; *Macropus* cf. *titan*.
EUTHERIANS: Muridae.

e. **V5381** 28°35'S, 138°13'E (KOPPERAMANNA).
Near Tilla Tilla Waterhole.
MARSUPIALS: Thylacoleonidae; ?*Thylacoleo* sp.
Diprotodontidae; *Diprotodon* cf. *optatum*.
Macropodidae; *Macropus* sp., *Protemnodon* sp., *Sthenurus* sp.
BIRDS: Dromornithidae.

f. **Malkuni Waterhole** (V5382) 28°34'S, 138°07'E (KOPPERAMANNA).
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.
Macropodidae; *Macropus* cf. *titan*, small Macropodid, *Protemnodon* cf. *anak*, *P.* cf. *brehus*, *Sthenurus* sp., *Procoptodon* cf. *goliah*.
BIRDS: Dromornithidae.
Phalacrocoracidae; *Phalacrocorax carbo*, *P. varius*.
Tytonidae; *Tyto* cf. *novaehollandiae*.

g. **V5859** 28°33'S, 138°09'E (KOPPERAMANNA).
MARSUPIALS: Dasyuridae; *Sarcophilus* sp.
Diprotodontidae; *Diprotodon* cf. *minor*.
Macropodidae; ?*Procoptodon* sp.
BIRDS: Phalacrocoracidae; *Phalacrocorax* sp.
REPTILES: Crocodilians.
FISH: Ceratodontidae; *Epiceratodus* sp.

h. **V5860** 28°35'S, 138°05'E (KOPPERAMANNA).
MARSUPIALS: Dasyuridae; *Sarcophilus* sp.
Vombatidae; *Phascolonus* cf. *gigas*.
Phalangeridae; *Trichosurus* cf. *vulpecula*.
Diprotodontidae; *Diprotodon* sp., *D.* cf. *minor*, ?*Nototherium*.
Macropodidae; *Bettongia* cf. *lesueur*, *Macropus* cf. *titan*, *Lagorchestes* sp., ?*Onychogalea* sp., *Protemnodon* sp., *P.* cf. *brehus*, *Sthenurus* sp., *S.* cf. *andersoni*, *S.* cf. *brownei*, *Procoptodon* cf. *goliah*, *P.* cf. *rapha*
EUTHERIANS: Muridae.
BIRDS: Dromornithidae.
REPTILES: Varanidae; *Megalania* sp.
Chelonians and Crocodilians.

i. **V5861** 28°34'S, 138°05'E (KOPPERAMANNA).
Katipiri Waterhole (Cuttapirra Waterhole).
MARSUPIALS: Vombatidae; *Phascolonus* cf. *gigas*.
Diprotodontidae; *Diprotodon* sp., ?*Zygomaturus* sp.
Macropodidae; ?*Wallabia* sp., *Protemnodon* cf. *anak*, *Sthenurus* sp., *S.* cf. *tindalei*, *Procoptodon* cf. *goliah*.
BIRDS: Dromornithidae.
Anhingidae; *Anhinga* sp.
REPTILES: Varanidae; *Megalania* sp.
Chelonians and Crocodilians.
FISH: Ceratodontidae.

j. **V5866** 24°34'S, 138°00'E (LAKE EYRE/KOPPERAMANNA).
MARSUPIALS: Vombatidae; *Phascolonus* sp.
Diprotodontidae; *Diprotodon* sp., ?*Zygomaturus* sp.
Macropodidae; *Protemnodon* cf. *brehus*, *Sthenurus* cf. *andersoni*, *S.* cf. *tindalei*, *Procoptodon* sp.
BIRDS: Anhingidae; *Anhinga* sp.
Phalacrocoracidae; *Phalacrocorax carbo*.
Anatidae; *Biziura* sp.

REPTILES: Varanidae; *Megalania* sp.
Chelonians and Crocodilians.
FISH: Siluriformes and Dipnoi.

k. **V5868** 28°32'S, 137°59'E (LAKE EYRE).
MARSUPIALS: Diprotodontidae.
Macropodidae.
BIRDS: Unidentified material.

l. **V6147** 28°34'S, 138°09'E (LAKE EYRE).
MARSUPIALS: Thylacoleonidae; *Thylacoleo* sp.
Diprotodontidae; *Diprotodon* sp.
Macropodidae.
EUTHERIANS: Muridae; *Rattus* sp.
BIRDS: Phalacrocoracidae; *Phalacrocorax* sp.
REPTILES: Varanidae; *Megalania* sp.
Crocodilians.
FISH: Unidentified material.
CRUSTACEANS: Decapods.

m. **Unnamed locality**, approx. 28°00'S, 139°30'E (INNAMINCKA).
Far NE South Australia, near Cooper Creek. Tooth recovered by drilling crew. **SAM.**
MARSUPIALS: Diprotodontidae.
Tate (1886), Stirton *et al.* (1961), Rich *et al.* (1978), Rich (1979), Tedford (pers. comm. 1980).

12. **LAKE PALANKARINNA** 28°46'S, 138°25'E (KOPPERAMANNA)
East of L. Eyre.

a. **Channel Sand Locality** (V5854).
Near the top of escarpment about 500 m north of Turtle Locality. Katipiri Sands (Late Pleistocene), incising Tirari Formation. **UCMP.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.
Macropodidae.
Birds, Teleost fish, Chelonian and Crocodilian remains.

b. **Mullet Locality** (V71173).
Small bluff 25 m NNW of Keane Quarry (V6265). Katipiri Sands (Late Pleistocene) overlying Etadunna Formation and overlain by Tirari Formation. **FUSA, UCMP.**
MARSUPIALS: Diprotodontidae; *Zygomaturus* sp.
Macropodidae; *Protemnodon* sp., ?*Prionotemnus* sp.
Fish and Crocodilian remains.
Stirton *et al.* (1961), Rich *et al.* (1978), Rich (1979).

13. **HERGOTT SPRINGS** 29°37'S, 138°04'E (MARREE).
3 km north of Marree. Mandible, **SAM.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.

14. **WELCOME SPRINGS** 29°40'S, 137°50'E (CURDIMURKA).
15 km SW of Marree. Hard green pebbly clay, cemented by calcium carbonate from mound spring. Mandible and bone fragments. **SAM, FUSA.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.

15. **MURNPEOWIE** 29°35'S, 139°03'E (MARREE).
100 km east of Marree. Mandible, **SAM.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.

16. **LAKE CALLABONNA** 29°50'S, 140°10'E (CALLABONNA).
NE South Australia. Gypsiferous lacustrine clays and sands, Millyera Formation. **SAM, AMNH, UCMP, SI.**
MARSUPIALS: Vombatidae; *Phascolonus gigas.*
Diprotodontidae; *Diprotodon* spp(?).
Macropodidae; *Macropus* spp., Protemnodon sp., *Sthenurus* sp. nov., *S. tindalei* (Wells & Tedford in prep.).
BIRDS: Dromaiidae; *Dromaius* sp.
Dromornithidae; *Genyornis newtoni.*
Unidentified smaller bird remains.
Tate (1893), Brown (1894), Stirling & Zietz (1896, 1900), Stirling (1900, 1913), Howchin (1930), Hale (1956), Tedford (1966, 1973), Callen & Tedford (1976), Callen (1977), Rich (1979), Wells & Tedford (in prep.)

17. **BILLEROO CREEK** 31°08'S, 140°15'E (CURNAMONA).
20 km SE of L. Frome. Red, sandy fluviatile Eurinilla Formation (Late Pleistocene). **SAM, FUSA, NMV, AMNH.**
MARSUPIALS: Vombatidae; *Lasiorhinus* sp.
Thylacoleonidae; *Thylacoleo carnifex.*
Diprotodontidae; *Diprotodon* sp.
Macropodidae; *Bettongia* sp., cf. *Propleopus* sp., *Macropus* sp., *M.* cf. *ferragus, Osphranter* sp., *Sthenurus* sp. nov., *S. tindalei, Sthenurus* sp., *Procoptodon goliah.*
EUTHERIANS: Muridae; *Leporillus* sp., *Conilurus* sp., *Rattus* sp., *Pseudomys* sp.
BIRDS: Dromaiidae; *Dromaius* sp.
Dromornithidae; *Genyornis newtoni.*
Tate (1886), Callen & Tedford (1976), Callen (1977), Wells & Tedford (in prep.).

18. **PERNATTY LAGOON** 31°37'S, 137°16'E (TORRENS).
50 km SE of Woomera. Weathered skeleton, fragments. **SAM.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.
Pledge (1974).

19. **HOOKINA CREEK** 31°44'S, 138°14'E (PARACHILNA)
25 km NW of Hawker. Valley-fill alluvium and red over-bank deposits of the Pooraka Formation (Late Pleistocene). **SAM, FUSA.**
MARSUPIALS: Dasyuridae; cf. *Dasycercus* sp., ?*Sarcophilus* sp., unidentified small dasyurid.
Peramelidae.
Vombatidae; *Lasiorhinus* sp., cf. *Vombatus* sp.
Diprotodontidae; *Diprotodon* sp.
Macropodidae; cf. *Potorous* sp., *Macropus* cf. *giganteus, M.* cf. *eugenii, Macropus* sp., *Osphranter* sp., *Wallabia* sp., *Propleopus oscillans,* unidentified small macropod.

EUTHERIANS: Muridae; *Hydromys chrysogaster, Leporillus conditor, Pseudomys hermannsburgensis*, unidentified rodent.
BIRDS: Dromaiidae; *Dromaius* sp.
Dromornithidae; *Genyornis* sp.
Unidentified small bird.
REPTILES: Elapidae; unidentified genus.
Varanidae; *Varanus cf. giganteus.*
Scincidae; *Trachydosaurus* sp., unidentified small lizards.
AMPHIBIANS: Unidentified frogs.
FISH: Unidentified small fish.
Daily (1956), Twidale (1966), Williams & Polach (1971), Williams (1973), Williams (in prep.).

20. **MOUNT EYRE** 31°46'S, 138°13'E (PARACHILNA).
26 km NW of Hawker. Western piedmont slope of ranges. Weathered skeleton on flat of sandy clay **SAM.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.
Daily (1956).

21. **WILLOCHRA CREEK** 32°15'S, 138°05'E (ORROROO).
8 km N of Quorn. Encrusted skull. **SAM.**
MARSUPIALS: Macropodidae; *Macropus* sp.

22a. **BOOLCUNDA CREEK** 32°13'S, 138°18'E (ORROROO).
"Langwarren" 30 km NE of Quorn. Red clay and gravel of dissected outwash fan. Mandible fragment (casts). **SAM.**
MARSUPIALS: Diprotodontidae: *Zygomaturus* sp.
Twidale (1966).

22b **BOOLCUNDA CREEK** 32°13'S, 138°31'E (ORROROO).
Unnamed tributary, 18 km south of Craddock. **FUSA.**
MARSUPIALS: Macropodidae; *Procoptodon* sp.
Williams (in prep.).

22c **BOOLCUNDA CREEK** approx. 32°20'S, 138°30'S (ORROROO).
Note with specimen: "NE corner Mookra on Boolcunda Creek 50 ft below surface in sand with wash in cavernous part of manganite lode." **AUGM.**
MARSUPIALS: Macropodidae; *Protemnodon* sp.

23. **BUCKALOWIE CAVES** 32°08'S, 138°55'E (ORROROO).
60 km SE of Hawker. Mairs Cave (F 3), Clara St Dora Cave (F 4). Bone generally encrusted with calcite. **SAM.**
MARSUPIALS: Dasyuridae; *Dasyurus* sp., *Sarcophilus harrisii*
Thylacinidae; *Thylacinus cynocephalus.*
Peramelidae.
Thylacoleonidae; *Thylacoleo carnifex.*
Macropodidae; *Bettongia* sp., *Potorous* sp., *Macropus* sp.
EUTHERIANS: Muridae.
BIRDS: Unidentified.
REPTILES: Unidentified.
Winton (1922).

24. **TEETULPA** 32°15'S, 139°40'E (CURNAMONA).
40 km NE of Yunta. Note with specimen: "Brady's Gully Teetulpa, 14 feet from surface in the drift 1888". **SAM.**
MARSUPIALS: Macropodidae; *Procoptodon* cf *rapha.*
Brown (1888).

25. **DEMPSEY'S LAKE** 32°28'S, 137°42'E (PORT AUGUSTA).
5 km NW of Pt. Augusta. Red aeolian sands of the Pooraka Formation (Late Pleistocene). **SAM, FUSA.**
MARSUPIALS: Dasyuridae; *Dasyurus* cf. *viverrinus, Sarcophilus harrisii.*
Vombatidae; *Phascolonus* cf. *gigas, Lasiorhinus latifrons.*
Diprotodontidae; *Diprotodon* sp.
Macropodidae; *Bettongia lesueur, B. penicillata, Macropus* sp., *Macropus* cf. *ferragus, Osphranter* sp., *Protemnodon brehus.*
BIRDS: Dromaiidae; *Dromaius* sp.
Dromornithidae; *Genyornis* sp.
?Anatidae
REPTILES: Elapidae.
Scincidae; *Trachydosaurus* sp.
Cooper (1959), Williams (1973), Williams (1976).

26. **ARNOLD'S BANK** 32°22'S, 137°46'E (PORT AUGUSTA).
15 km north of Pt. Augusta. Red sand dune in area of dunes and salt flats, head of Spencer Gulf. Pooraka Formation (Late Pleistocene). **SAM.**
MARSUPIALS: Diprotodontidae: *Diprotodon* sp.
Williams (1976).

27. **HILLPARA CREEK** 32°31'S, 138°55'E (ORROROO).
30 km NE of Orroroo. Red clayey alluvium associated with creek. **SAM.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.
Macropodidae; *Sthenurus* sp.
Hale (1956), Daily (1960b), Twidale (1966), Williams (in prep.).

28. **NECTAR BROOK** 32°42'S, 137°56'E (PORT AUGUSTA).
28 km SSE of Pt. Augusta. Red alluvium exposed during dam excavation in 1898. **SAM.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.
Macropodidae; *Macropus* sp.

29. **PEKINA CREEK** 32°44'S, 138°37'E (ORROROO)
2 km south of Orroroo. Greenish lacustrine clays exposed on SE shore of reservoir, and poorly-sorted alluvium below dam wall. *Macropus* sp. has

also been recovered from a well excavation 18 m deep on Pekina Creek floodplain. **SAM, FUSA.**
MARSUPIALS: Vombatidae.
Diprotodontidae; *Diprotodon* sp.
Macropodidae; *Bettongia* sp., *Macropus* sp.
Howchin (1909), Williams (in prep.)

30. **BLACK ROCK GRAVEL PIT** 32°47'S, 138°40'E (ORROROO).
8 km south of Orroroo. Disused gravel pit on alluvial plain. Sinuous channel deposit of fine, rounded gravel with red sandy matrix. **SAM.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.
Macropodidae; *Macropus* sp., *Protemnodon* sp., *Sthenurus* sp.

31. **MANUNDA CREEK** 32°56'S, 139°21'E (ORROROO).
40 km east of Peterborough. Red clayey overbank deposit of creek. **SAM.**
MARSUPIALS: Macropodidae; *Procoptodon* sp.
Edwards (1964).

32. **PORT PIRIE GRAVEL PIT** 33°15'S, 138°05'E (BURRA).
3 km south of Pt. Pirie, western flank of ranges. Clean coarse quartz gravel. **SAM.**
MARSUPIALS: Thylacoleonidae; *Thylacoleo* sp.
Diprotodontidae; *Diprotodon* sp.
Macropodidae; *Macopus* sp., *M.* cf. *titan*, *Sthenurus* sp.
Pledge (1973, 1974).

33. **WAUPUNYAH CREEK** 33°15'S, 139°05'E (BURRA).
8 km east of Terowie. Red clayey alluvium of creek. **SAM, FUSA.**
MARSUPIALS: Vombatidae; cf. *Lasiorhinus* sp.
Diprotodontidae; *Diprotodon* sp.
Macropodidae; *Macropus* spp., *Osphranter* sp., *Procoptodon* sp.
Williams (in prep.).

34. **ULOOLOO** 33°19'S, 138°58'E (BURRA).
35 km north of Burra. Piedmont and alluvial deposits of Irwin and Terowie Creeks. **SAM, FUSA.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.
Macropodidae; *Procoptodon* sp.
Williams (in prep.).

35. **COLLINSVILLE** 33°20'S, 139°08'E (BURRA).
50 km NE of Burra. Red silty floodplain deposit in Witta Creek valley, exposed by modern gullying. **SAM, FUSA.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.
Macropodidae; *Macropus* spp., *Procoptodon* sp.
Williams (in prep.).

36. **NEWIKIE CREEK** 33°30'S, 139°10'E (BURRA)
25 km NE of Burra. Alluvial fan sands and gravels. **SAM, FUSA.**
MARSUPIALS: Vombatidae; *Lasiorhinus* sp.
Diprotodontidae; *Diprotodon* sp.
Macropodidae.
Williams (in prep.).

37. **BALDINA CREEK** 33°41'S, 139°04'E (BURRA).
13 km east of Burra. Red silty valley alluvium and fan. **SAM, FUSA.**
MARSUPIALS: Vombatidae; *Lasiorhinus* sp.
Thylacoleonidae; *Thylacoleo carnifex*.
Diprotodontidae; *Diprotodon* sp.
Macropodidae; *Bettongia* sp., *Macropus* spp., *Protemnodon* sp, *Sthenurus* cf. *atlas*.
BIRDS: Dromornithidae; *Genyornis newtoni*
Tate (1890), Zietz (1890), Stirling & Zietz (1896, 1913) Stirling (1900), Howchin (1930), Hale (1956), Rich (1979), Williams (in prep.).

38. **BUTE** 33°52'S, 138°01'E (BURRA).
20 km SW of Snowtown. Material associated with human remains A25805, from a sand dune. Probably Holocene. Anthropology Collection. **SAM.**
MARSUPIALS: Macropodidae; *Macropus* sp.
BIRDS: Dromaiidae; *Dromaius* sp.

39. **BURRA CREEK** 33°52'S, 139°09'E (BURRA).
30 km SE of Burra. Brown silts, sands, and gravels of alluvial fan. **FUSA.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.
Macropodidae.
REPTILES: Unidentified small lizards.
AMPHIBIANS: Unidentified frogs.
Chapman & Mawson (1925), Williams (in prep.).

40. **BUNDEY** 33°53'S, 139°18'E (BURRA).
40 km SE of Burra, "Gum Creek". Red clay exposed by dam excavations in 1889 and 1953. **SAM.**
MARSUPIALS: Dasyuridae; *Sarcophilus* cf. *ursinus*.
Thylacoleonidae; *Thylacoleo carnifex*.
Diprotodontidae; *Diprotodon* spp(?).
Macropodidae; ?*Sthenurus* sp.
Zietz (1890), Stirling (1900), Howchin (1930), Pledge (1977), Williams (in prep.).

41. **MORGAN** 34°02'S, 139°40'E (RENMARK)
River Murray flats, north bank, where cliffs are cut by tributary from the NW. **SAM.**
MARSUPIALS: Vombatidae; *Phascolonus* sp.
Diprotodontidae; *Diprotodon* sp.
Macropodidae; *Macropus* sp.
N. S. Pledge (pers. comm. 1979).

42. **CHOWILLA** 34°01'S, 140°50'E (RENMARK).
North of Renmark. Excavation for proposed Chowilla Dam wall, 18 m deep. **SADME.**
MARSUPIALS: Vombatidae; *Phascolonus* sp.
Firman (1966), Marshall (1973).

43. **CURRAMULKA** 34°42'S, 137°44'E (MAITLAND).
a. Town Cave (Y 2) in Curramulka. Red, stony

clay with flowstone. Bone generally encrusted with calcite. **SAM, FUSA, UCMP.**
MARSUPIALS: Dasyuridae; *Dasyurus* sp.
Peramelidae; *Perameles* sp.
Vombatidae; *Lasiorhinus* sp.
Thylacoleonidae; *Thylacoleo carnifex*, *T. hilli*.
Diprotodontidae; cf. *Nototherium* sp.
Macropodidae; *Macropus* sp., *Protemnodon* sp., *Wallabia* sp., *Sthenurus* spp., *Procoptodon* sp.
EUTHERIANS: Muridae.

b. **Quarry** 2 km south of Curramulka. Red calcite-cemented bone breccia filling fissures in Early Cambrian limestone. **SAM, FUSA.**
MARSUPIALS: Vombatidae; *Lasiorhinus* sp.
Macropodidae; *Macropus* sp., *Procoptodon* sp.
Pritchard (1891), Howchin (1925), Dally (1960a, 1960b), Pledge (1977).

44. **LAKE FOWLER** 35°05'S, 137°37'E (KINGSCOTE).
Southern Yorke Peninsula. Gypsum lunette on east shore of lake. Fossils exposed by quarrying. **SAM.** (J. A. McNamara 1974, Undergraduate project, Zoology Dept, University of Adelaide, unpub.)
MARSUPIALS: Dasyuridae: *Sarcophilus* cf *ursinus*
Peramelidae; *Macrotis* cf. *lagotis*.
Vombatidae; *Lasiorhinus* sp.
Thylacoleonidae; *Thylacoleo carnifex*.
Macropodidae; *Bettongia lesueur*, *Macropus* cf. *ferragus*, *M.* cf. *eugenii*, *Onychogalea* sp.
EUTHERIANS: Muridae; *Leporillus* sp.
Howchin (1900), Jack (1921), King (1950).

45. **PONDALOWIE BAY** 35°14'S, 136°50'E (KINGSCOTE).
SW Yorke Peninsula, near one of the lakes at Pondalowie. Calcareous claystone slab with trackways. ?Holocene. **SAM.**
MARSUPIALS: Macropodidae: ?*Macropus* sp.
BIRDS: Dromaiidae; ?*Dromaius* sp

46. **ROCKY RIVER** 35°55'S, 136°47'E (KINGSCOTE).
Western end of Kangaroo Island. Swamp deposit. **SAM.**
MARSUPIALS: Dasyuridae; *Sarcophilus* sp.
Vombatidae; Unidentified genera.
Phascolarctidae; *Phascolarctos cinereus*.
Phalangeridae; *Trichosurus vulpecula*.
Diprotodontidae; *Diprotodon* sp., *Zygomaturus trilobus*
Macropodidae; *Macropus fuliginosus*, *M. eugenii*, *Protemnodon* sp., *Sthenurus* spp., *S. gilli*.
EUTHERIANS: Muridae.
BIRDS: Dromaiidae; *Dromaius* sp.
Jones (1923) Tindale *et al.* (1935), Hale (1956), Pledge (1975, 1979), J. H. Hope (pers. comm. 1980).

47. **KELLY HILL CAVES** (K1–4, 14, 34) 35°59'S, 136°54'E (KINGSCOTE).
SW Kangaroo Island. **SAM.**
MARSUPIALS: Dasyuridae; *Dasyurus maculatus*, *Sarcophilus harrisii*, *Phascogale tapoatafa*.
Vombatidae; *Lasiorhinus* sp.
Phascolarctidae; *Phascolarctos cinereus*.
Phalangeridae; *Trichosurus vulpecula*.
Petauridae; *Pseudocheirus peregrinus*.
Macropodidae; *Macropus fuliginosus*, *M. eugenii*, *Sthenurus* cf. *occidentalis*.
BIRDS: Dromaiidae; *Dromaius diemenianus*.
Howchin (1930), Hale (1956), Hope *et al.* (1977), Pledge (1979), R. T. Wells (pers. comm. 1979).

48a. **MOUNT TAYLOR CAVE** (K6) 35°58'S, 137°03'E (KINGSCOTE).
SW Kangaroo Island, 5 km east of Mt Stockdale. **SAM.**
MARSUPIALS: Macropodidae; *Sthenurus* sp.
Pledge (1979).

48b. **EMU FOUR HOLE CAVE** (K20) 35°59'S, 136°54'E (KINGSCOTE).
SW Kangaroo Island, near Mt Taylor. Subfossil to modern bones (Pledge 1979). **SAM.**
MARSUPIALS: Dasyuridae; *Dasyurus viverrinus*, *Sminthopsis murina*.
Peramelids; *Perameles* sp., *Isoodon obesulus*.
Phalangeridae; *Trichosurus vulpecula*.
Petauridae; *Pseudocheirus peregrinus*.
Burramyidae; *Cercartetus concinnus*.
Macropodidae; *Potorous platyops*, *Macropus fuliginosus*, *M. eugenii*.
MONOTREMES: Tachyglossidae; *Tachyglossus aculeatus*.
EUTHERIANS: Muridae; *Rattus fuscipes*, *R. lutreolus*.
BIRDS: Dromaiidae; *Dromaius diemenianus*.
Hale (1956), Pledge (1979).

48c. **FOSSIL CAVE** (K21) 35°59'S, 136°54'E (KINGSCOTE).
Adjacent to Emu Four Hole Cave, SW Kangaroo Island. **SAM.**
MARSUPIALS: Dasyuridae; *Sarcophilus* cf. *harrisii*.
Vombatidae.
Phascolarctidae; *Phascolarctos cinereus*
Macropodidae; *Macropus fuliginosus*, *M. eugenii*, *Sthenurus* cf. *brownei*.
EUTHERIANS: Muridae.
Pledge (1979).

48d. **SETON ROCK SHELTER** (K30) 35°59'S, 137°03'E (KINGSCOTE).
SW Kangaroo Island. Archaeological; sandy sediments excavated to a depth of about 2 m. **SAM.**
MARSUPIALS: Dasyuridae; *Dasyurus* cf. *geoffroi*/*viverrinus*, *D. maculatus*, *Sarcophilus harrisii*.
Peramelidae; *Perameles bougainville*, *Isoodon obesulus*
Vombatidae; *Lasiorhinus latifrons*
Phalangeridae; *Trichosurus vulpecula*.
Burramyidae; *Cercartetus lepidus*.

Macropodidae; *Bettongia penicillata, B. lesueur, Potorous platyops, Macropus* cf. *fuliginosus, M. greyi, M. rufogriseus,* cf. *Megaleia rufa, Lagorchestes leporides, Sthenurus* cf. *gilli.*
EUTHERIANS: Muridae; *Hydromys chrysogaster, Rattus fuscipes greyi, R. lutreolus, Mastacomus fuscus, Pseudomys occidentalis, P. australis/shortridgei.*
BIRDS: Procellariidae; *Pachyptila* cf. *salvini, Puffinis* sp.
Plataleidae; *Threskiornis* cf. *molucca.*
Anatidae; cf. *Anseranas semipalmata, Tadorna* cf. *tadornoides, Anas* cf. *superciliosa, Anas* cf. *castanea, Malacorhynchus membranaceus.*
Accipitridae; *Hieraaetus morphnoides.*
Falconidae; *Falco berigora.*
Phasianidae; *Coturnix* cf. *pectoralis.*
Turnicidae; *Turnix varia, T. velox*
Rallidae; *Rallus philippensis, R. pectoralis, Porzana* cf. *fluminea, Gallinula (Tribonyx)* cf. *mortierii, G. (Tribonyx)* cf. *ventralis.*
Burhinidae; *Burhinus magnirostris.*
Scolopacidae; *Gallinago* cf. *hardwickii.*
Laridae; *Larus novaehollandiae, Sterna* cf. *nereis.*
Columbidae; *Ocyphaps lophotes.*
Platycercidae; *Pezoporus wallicus, Lathamus discolor.*
Hirundinidae; *Hirundo* cf. *tahitica, Petrochelidon nigricans.*
Meliphagidae.
Sylviidae; *Cinclorhamphus cruralis.*
Grallinidae; *Grallina cyanoleuca.*
Cracticidae; *Gymnorhina tibicen, Strepera graculina, S. versicolor.*
Corvidae; *Corvus* sp.
Unidentified passerines.
REPTILES: Elapidae.
Varanidae; *Varanus* sp.
Scincidae; *Trachydosaurus rugosus, Tiliqua nigrolutea,* cf. *Egernia whitii.*
Agamidae; *Amphibolurus* spp.
MOLLUSCS: Marine molluscs of archaeological origin, and terrestrial/aquatic molluscs
Hope *et al.* (1977).

49. **HOG BAY RIVER** 35°49'S, 137°57'E (KINGSCOTE).
Eastern Kangaroo Island. Found in "Pleistocene drift" (Catalogue). **SAM.**
MARSUPIALS: Macropodidae; *Macropus* sp.

50. **KAPUNDA** 34°23'S, 139°00'E (ADELAIDE).
South of Kapunda. Bones and teeth in matrix. **SAM.**
MARSUPIALS: Vombatidae; *Phascolonus* sp.
Jack (1919), Johns (1967).

51. **TWO WELLS** 34°36'S, 138°31'E (ADELAIDE).
35 km north of Adelaide. Sandpit "near Two Wells" (note with mandible). **SAM.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.

52. **GAWLER** 34°35'S, 138°45'E (ADELAIDE)
40 km north of Adelaide. Excavations on banks of Gawler and South Para Rivers. **SAM.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.
Stirling (1900), Howchin (1930), Hale (1956).

53. **YATALA** 34°51'S, 138°37'E (ADELAIDE).
NE suburb of Adelaide. Jaw "9 feet below the surface in a bed of gravel" (Moncrieff 1882). Location of specimen unknown.
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.
Moncrieff (1882).

54. **FROMM'S LANDING** 34°46'S, 139°33'E (RENMARK).
River Murray, near Walker Flat. Archaeological; rock shelter. **SAM.**
NOTE: The assemblages summarised here do not distinguish the numerous stratigraphic levels recognised by Mulvaney *et al.* (1964).

a. **Shelter 2.**
MARSUPIALS: Dasyuridae; *Dasyurus geoffroi, Dasyurops maculatus, Sarcophilus harrisii, Dasycercus cristicaudata, Antechinus flavipes, A. swainsonii, Sminthopsis* cf. *murina, Myrmecobius fasciatus.*
Thylacinidae; *Thylacinus cynocephalus.*
Peramelidae; *Perameles bougainville,* cf *Isoodon obesulus, Chaeropus ecaudatus.*
Vombatidae; cf. *Lasiorhinus latifrons.*
Phalangeridae; *Trichosurus vulpecula.*
Petauridae; *Pseudocheirus peregrinus.*
Macropodidae; *Bettongia penicillata, B. lesueur, Potorous morgani, Macropus canguru, Thylogale eugenii, Onychogalea lunata, Lagorchestes leporides, Lagostrophus fasciatus.*
EUTHERIANS: Canidae; *Canis familiaris dingo.*
Muridae; *Hydromys chrysogaster, R. greyi, Rattus lutreolus,* cf. *Pseudomys auritus, Thetomys* sp., cf. *Notomys* sp., *Conilurus albipes.*
Mulvaney *et al.* (1964), Archer (1971).

b. **Shelter 6.**
MARSUPIALS: Dasyuridae: *Myrmecobius fasciatus*
Peramelidae; *Perameles bougainville, Isoodon obesulus, Chaeropus ecaudatus.*
Phalangeridae; *Trichosurus vulpecula.*
Macropodidae; *Bettongia penicillata, Macropus canguru, Thylogale eugenii, Lagorchestes leporides, Lagostrophus fasciatus.*
EUTHERIANS: Canidae; *Canis familiaris dingo.*
Muridae; *Hydromys chrysogaster, R. greyi, Rattus lutreolus*
Mulvaney *et al.* (1964).

55. **DEVON DOWNS** 34°41'S, 139°37'E (RENMARK).
River Murray, north of Mannum. Archaeological; rock shelter. **SAM.** Note: The assemblages summarised here do not distinguish the numerous stratigraphic levels recognised by Hale & Tindale (1930). See also M. Smith, 1977 B.Sc. (Hons)

thesis, Aust. Nat. Univ., Dept of Prehistory & Anthropology (unpub.).
MARSUPIALS: Dasyuridae; *Dasyurus viverrinus, D. geoffroyi, Sarcophilus harrisii, Phascogale flavipes.*
Peramelidae; *Perameles myosura, Isoodon obesulus.*
Vombatidae; *Lasiorhinus* sp.
Phalangeridae; *Trichosurus vulpecula.*
Petauridae; *Pseudocheirus* sp.
Macropodidae; *Bettongia* sp., *Potorous* sp., *Macropus* sp., *Macropus* cf. *giganteus, Thylogale* sp., *Lagorchestes leporides.*
EUTHERIANS: Canidae; *Canis familiaris dingo.*
Muridae; *Hydromys chrysogaster, Rattus* sp.
BIRDS: Dromaiidae; *Dromaius novaehollandiae.*
Anatidae; *Querquedula* sp., *Chenopis atrata, Biziura lobata.*
Accipitridae; *Uroaetus audax.*
REPTILES: Boidae; *Python spilotes.*
Varanidae; *Varanus* cf. *gouldii.*
Scincidae; *Trachysaurus rugosa, Tiliqua* sp.
Agamidae; *Amphibolurus* sp.
TORTOISES: Chelidae; *Chelodina longicollis, Emydura macquarii.*
FISH: Macculochellidae; *Oligorus macquariensis.*
Plotosidae: *Tandanus tandanus.*
Plectroplitidae; *Plectroplites ambiguus.*
INVERTEBRATES: A range of molluscs and crustaceans.
Hale & Tindale (1930).

56. **CHUCKA BEND** 34°53'S, 139°39'E (RENMARK).
River Murray, north of Mannum. Site details and location of specimens unknown.
MARSUPIALS: Vombatidae; *Phascolonus* sp.
Stirling (1913), Howchin (1930).

57. **ADELAIDE AREA** 34°55'S, 138°35'E (ADELAIDE).
A number of sites which appear to be associated with alluvium of the River Torrens.

a. **Allenby Gardens** 34°53'S, 138°34'E (ADELAIDE).
Adjacent to NW corner of Adelaide city. Specimens found "Approx. 20 ft. below the surface" (SAM Catalogue).
MARSUPIALS: Diprotodontidae; *Diprotodon* sp., cf. *Nototherium* sp.

b. **Brompton** 34°54'S, 138°34'E (ADELAIDE).
Adjacent to NW corner of Adelaide city; 20, East Street, Brompton. Note with specimens, "25 feet below surface" in black clay. **SAM.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.

c. **Croydon** 34°53'S, 138°34'E (ADELAIDE).
Adjacent to NW corner of Adelaide city. Several localities "within two and three miles of Croydon" (Tate 1890). "Found on Mr Woodhouse's property (South of Railway line West from Croydon Railway Station) at Croydon about 5–6 ft below the surface in an old river bed of sharp sand and gravel". (Note with specimens.) **SAM.**
MARSUPIALS: Vombatidae; cf. *Phascolomys* sp.
Diprotodontidae; *Diprotodon* sp.
Tate (1890).

d. **Findon** 34°55'S, 138°32'E (ADELAIDE).
Western suburb of Adelaide. One of numerous gravel pits. **SAM.**
MARSUPIALS: Vombatidae; Unidentified mandible.
Diprotodontidae; *Diprotodon* sp.
BIRDS: "?Bird bone" catalogued.
Howchin (1913).

e. **Kirkaldy Pit** 34°55'S, 138°30'E (ADELAIDE).
Western suburb of Adelaide. One of numerous gravel pits. **SAM.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.

f. **Thebarton** 34°55'S, 138°34'E (ADELAIDE).
Adjacent to west side of Adelaide city. Rib bone from "a depth of six feet" (Waterhouse 1882). Origin of *P. azael* jaw not known. **SAM.**
MARSUPIALS: Diprotodontidae; *Palorchestes azael.*
Waterhouse (1882).

58. **HALLETT COVE** 35°04'S, 138°30'E (ADELAIDE).
Southern coastal suburb of Adelaide. Waterworn molar from modern beach gravel, derived from cliff exposures of Pleistocene sediments. **SAM.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.

59. **ECHUNGA** 35°06'S, 138°48'E (BARKER).
30 km SE of Adelaide. Bone from "deep alluvium" (note with specimens). May be Tertiary. **SAM.**
MARSUPIALS: ?Macropodidae.

60a. **SALT CREEK** 35°28'S, 138°20'E (BARKER).
80 km south of Adelaide. Sulphurous black clays of swamp deposit. There is a New Salt Creek "four miles north of Cape Jervis" (Hale 1956), but Brown (1892) leaves no doubt that the site is near Normanville. **SAM.**
MARSUPIALS: Vombatidae; *Phascolonus gigas.*
Thylacoleonidae; *Thylacoleo carnifex.*
Diprotodontidae; *Diprotodon* sp.
Macropodidae; *Bettongia* sp., *Macropus* sp., *Osphranter* sp., *Sthenurus* sp., *Procoptodon* sp.
BIRDS: Dromaiidae; *Dromaius* sp.
Dromornithidae; *Genyornis newtoni.*
Unidentified bird remains.
REPTILES: Unidentified material.
FISH: Unidentified material.
Waterhouse (1880), Brown (1892), Stirling & Zietz (1896), Zietz (1907), Stirling (1913), Howchin (1930), Hale (1956), Ride (1967), Pledge (1977).

60b. **YANKALILLA** 35°28'S, 138°37'E (BARKER).
80 km south of Adelaide. Possibly the same site as Salt Creek. **SAM.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.

61. **GOOLWA** 35°31'S, 138°45'E (BARKER).
70 km south of Adelaide. Known as the "Goolwa Footprints", specimens actually taken from an eroding cliff at nearby Middleton Beach in 1938. Exposed below about 7 m of "sands, limestones etc. above the pipeclay on which the prints were made." (Letter by Fenner, 20th June, 1952; copy with originals and casts.) **SAM.**
MARSUPIALS: Unidentified footprints, approx. 150 mm long.

62. **BLACKFORD DRAIN** 36°46'S, 140°01'E (NARACOORTE).
21 km NE of Kingston, S.E. During placement of bridge pylons, fossils recovered from a depth of "11–13 feet", north side of creek, in a bed of waterworn stones. "Rock bottom" at 13 feet was "a hard stone which looked like a flow of black mud, thickly impregnated with small white shells". (Letter from R. V. Flint with specimens.) **SAM.**
MARSUPIALS: Diprotodontidae; *Diprotodon* sp.
Macropodidae; *Macropus* spp., *Sthenurus* sp., cf. *Procoptodon* sp.

63. **NARACOORTE** 36°59'S, 140°45'E (NARACOORTE).
SE South Australia. Cave Sites. **SAM.**

a. **Henschke's Bone Dig** (U 91/97) Outskirts of Naracoorte at Henschke's Quarry. A diverse assemblage, mostly marsupial. Differs in detail from Naracoorte Caves deposits. (N. S. Pledge pers. comm. 1979). **SAM.**
MONOTREMES: Tachyglossidae; *Zaglossus ramsayi*
BIRDS: Megapodiidae; *Progura naracoortensis*.
AMPHIBIANS: Hylidae; *Litoria ewingi*.
Leptodactylidae; *Limnodynastes tasmaniensis*, *Ranidella signifera*.
van Tets (1974a), Tyler (1977), Pledge (in prep.).

b. **James' Quarry Cave** (U 29). Naracoorte township. **UCMP.**
MARSUPIALS: Thylacoleonidae; *Thylacoleo carnifex*.
Daily (1960a)

64. **NARACOORTE CAVES** 37°01'S, 140°48'E (PENOLA).
15 km SE of Naracoorte. Numerous caves, usually with red sandy cave fill containing fossils. **SAM. FUSA.**

a. **Alexandra Cave** (U 3).
Old collection: **SAM.** Recently collected: **FUSA.**
MARSUPIALS: Thylacoleonidae; *Thylacoleo carnifex*.
Macropodidae; *Sthenurus* cf. *occidentalis*, *Sthenurus* sp., *Procoptodon* sp.

b. **Brown Snake Cave** (U 14).
SAM collection.
MARSUPIALS: Macropodidae; *Sthenurus* sp.

c. **Cathedral Cave** (U 12/13).
SAM collection.
MARSUPIALS: Thylacoleonidae; *Thylacoleo carnifex*.

d. **Dogs Prohibited Cave** (U –).
FUSA collection.
MARSUPIALS: Dasyuridae; *Dasyurus* sp.
Peramelidae.
Macropodidae; *Potorous* sp., *Macropus* sp.
EUTHERIANS: Muridae.
BIRDS: Unidentified material.

e. **Fox Cave** (U 22).
SAM collection.
MARSUPIALS: Dasyuridae: *Dasyurus* sp., *Sarcophilus* sp.
Thylacinidae; *Thylacinus* sp.
Peramelidae; *Isoodon* sp.
Vombatidae; *Vombatus* sp.
Phalangeridae; *Trichosurus* sp.
Petauridae; *Pseudocheirus* sp.
Thylacoleonidae; *Thylacoleo carnifex*.
Macropodidae; *Bettongia* sp., *Potorous* sp., *Macropus* cf. *giganteus*, *M. rufogriseus*, *Sthenurus* sp., *S. gilli*.
BIRDS: Unidentified material.

f. **Haystall Cave** (U 23).
SAM collection.
MARSUPIALS: Dasyuridae: *Dasyurus* sp., *Sarcophilus laniarius*.
Phascolarctidae; *Phascolarctos* sp.
Thylacoleonidae; *Thylacoleo* sp.
Macropodidae; *Macropus* sp., *Sthenurus* sp.
REPTILES: Scincidae; *Tiliqua* sp.

g. **Specimen Cave** (U 35).
Previously known as Zietz Cave. **SAM.**
MARSUPIALS: Dasyuridae; *Sarcophilus laniarius*.
Thylacinidae; *Thylacinus* cf. *major*.
Peramelidae.
Vombatidae.
Thylacoleonidae; *Thylacoleo* sp.
Macropodidae; *Macropus* sp., *M.* cf. *titan*, *Protemnodon* cf. *anak*.

h. **Tomato-Stick Cave** (U 10/11).
SAM collection.
MARSUPIALS: Macropodidae; *Macropus* sp., *Protemnodon* sp.

i. **Victoria Fossil Cave** (U 1).
SAM, FUSA collections.
MARSUPIALS: Dasyuridae: *Dasyurus viverrinus*, *D. maculatus*, *Sarcophilus* sp., *Antechinus flavipes*, *A. stuartii*, *A. swainsonii*, *Sminthopsis crassicaudata*, *S. murina*.
Thylacinidae; *Thylacinus cynocephalus*.
Peramelidae; *Perameles gunnii*, *P. bougainville*, *Isoodon obesulus*.
Vombatidae; *Vombatus* sp.
Phascolarctidae; *Phascolarctos* sp.
Petauridae; *Pseudocheirus peregrinus*, *Petaurus breviceps*.
Burramyidae; *Cercartetus nanus*.
Thylacoleonidae; *Thylacoleo carnifex*

Diprotodontidae; *Palorchestes azael, Zygomaturus trilobus.*
Macropodidae; *Bettongia penicillata, B. gaimardi, Potorous apicalis, P. platyops, Macropus giganteus, M. rufogriseus, M. greyi, M. eugenii, M. titan, Wallabia bicolor, Protemnodon roechus, Sthenurus andersoni, S. atlas, S. brownei, S. gilli, S. maddocki, S. occidentalis, Procoptodon rapha,* small macropods.
MONOTREMES: Tachyglossidae; *Tachyglossus* sp., *Zaglossus* sp.
EUTHERIANS: At least six species of rodent (M. J. Smith in prep.).
BIRDS: Dromaiidae; *Dromaius novaehollandiae.*
Megapodidae; *Progura naracoortensis, Leipoa ocellata,* indeterminate species.
Phasianidae; *Coturnix pectoralis, C. australis.*
Turnicidae; *Turnix* sp., *T. varia.*
Pedionomidae; *Pedionomus torquatus.*
Rallidae; *Rallus philippensis.*
Charadriidae; *Peltohyas australis.*
Scolopacidae; *Tringa glareola, Gallinago hardwickii, Calidris ruficollis.*
Platycercidae; *Pezoporus wallicus.*
Tytonidae; *Tyto novaehollandiae.*
Grallinidae; *Grallina cyanoleuca.*
Craticidae; *Gymnorhina tibicen.*
REPTILES: Boidae; *Wonambi naracoortensis.*
Elapidae; *Pseudonaja* cf. *nuchalis, Notechis* cf. *scutatus, Pseudechis* cf. *porphyriacus,* Unidentified group.
Varanidae; *Varanus varius, V. gouldii.*
Scincidae; *Trachydosaurus rugosus, Tiliqua nigrolutea,* cf. *Sphenomorphus tympanum, Egernia* cf. *whitei.*
Agamidae; *Amphibolurus* cf. *barbatus.*
AMPHIBIANS: Hylidae; *Litoria ewingi.*
Leptodactylidae; *Limnodynastes* cf. *dumerili, Ranidella signifera, Geocrinea* cf. *laevis.*
Woods (1866), Smith (1971, 1972, 1976), van Tets (1974a), van Tets & Smith (1974), Wells (1975), Olson (1976), Wells & Nichol (1977), Tyler (1977), Murray (1979), Wells & Murray (1979), Wells (pers. comm. 1979).

65. **PENOLA** 37°23′S, 140°50′E (PENOLA).
22 km NNW of Penola. Bones found in sinking a well on the edge of a swamp. Whereabouts of fossils unknown.
BIRDS: Dromornithidae; cf. *Genyornis* sp.
Stirling & Zietz (1896, 1900), Rich (1979).

66a. **GLENCOE** 37°41′S, 140°37′E (PENOLA).
22 km NW of Mt Gambier. Probably a cave deposit, as fossils are white with red sediment adhering. Possibly Glencoe West Cave (L 77) or Glencoe East Cave (L 108). **SAM.**
MARSUPIALS: Macropodidae; *Macropus* sp., *Sthenurus* sp.
Tindale (1933).

66b. **GREEN WATERHOLE** (L 81) 37°44′S, 140°32′E (PENOLA).
22 km NW of Mt Gambier. Also known as Fossil Cave. Fossils from surface of rockpile to a depth of 15 m in water-filled cave. **SAM, FUSA.**
MARSUPIALS: Dasyuridae; *Dasyurus* sp., *Sarcophilus* sp.
Thylacinidae; *Thylacinus* sp.
Phalangeridae; *Trichosurus* sp.
Thylacoleonidae; *Thylacoleo carnifex.*
Macropodidae; *Bettongia penicillata, Propleopus oscillans, Macropus* sp., *Osphranter* sp., *Protemnodon* sp., *Wallabia* sp., *Sthenurus gilli, S. maddocki, S. occidentalis.*
EUTHERIANS: Muridae.
BATS: Unidentified material.
BIRDS: Dromornithidae; *?Genyornis* sp.
A diverse assemblage of other birds.
Wells & Murray (1979), Wells & Williams (in prep.), Rich & van Tets (in prep.), Pledge (in prep.).

66c. **MILLICENT** 37°36′S, 140°21′E (PENOLA).
Far SE of South Australia. Fossils found "at a depth of six feet below the surface, embedded in peat mixed with shells" (Waterhouse 1882). Accession card for SI states "18 in. below surface".
MARSUPIALS: Diprotodontidae; *Diprotodon* sp., *Zygomaturus* sp.
Waterhouse (1882).

66d. **MT BURR CAVE** (L 69/70) 37°32′S, 140°27′E (PENOLA).
Far SE of South Australia. **SAM.**
MARSUPIALS: Macropodidae; *Sthenurus* sp.

66e. **TANTANOOLA CAVE** (L 12) 37°43′S, 140°30′E (PENOLA).
Near Tantanoola. Cave in old wave-cut cliff. **SAM.**
MARSUPIALS: Dasyuridae; *?Sarcophilus* sp.
Vombatidae; *?Phascolomys* sp.
Phalangeridae; *Trichosurus* sp.
Macropodidae; *Sthenurus* sp., *Protemnodon roechus.*
EUTHERIANS: Otariidae; *Arctocephalus* sp.
Muridae; *Rattus* sp., *Hydromys* sp.
Tindale (1933).

67. **MOUNT GAMBIER** 37°50′S, 140°47′E (PENOLA).
Far SE of South Australia.

a. **Cave** exposed by earthworks in Derrington Street. **SAM.**
MARSUPIALS: Peramelidae; *Perameles* sp.
Phascolarctidae; *Phascolarctos* sp.
Phalangeridae; *Pseudocheirus* sp.
Thylacoleonidae; *Thylacoleo carnifex.*
Diprotodontidae; *Nototherium* sp.
Macropodidae; *Bettongia* sp., *Sthenurus* spp.

b. **Cave,** location unknown. **BMNH.**
BIRDS: Dromornithidae; *Genyornis* sp.
Stirling & Zietz (1896, 1900), Rich (1979).

c. **Cave** exposed by excavation in Gray Street. **SAM.**
MARSUPIALS: *Sthenurus* spp.

d. **Moorak** 37°52′S, 140°47′E (PENOLA).
5 km south of Mt Gambier. Probably a cave deposit. **SAM.**
MARSUPIALS: Thylacoleonidae; *Thylacoleo* sp. Macropodidae; *Sthenurus* sp.

68. **?TANKSTAND CAVE** (L 65) 37°57′S, 140° 40′E (PENOLA).
3 km west of Mt Shank; "Sec 823, Hd Macdonnell, Co Sturt" (SAM Catalogue). However, this should probably be County Grey, where there are numerous caves (Hundred Map, H. J. Wall, Govt Photolithographer, Adelaide, 1960).
MARSUPIALS: Macropodidae; *Sthenurus gilli*.

Alphabetical index to sites

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More detailed lists of fossil birds are to be found in P. V. Rich (1975) Antarctic dispersal routes, wandering continents and the origin of Australia's non-passeriform avifauna. *Mem. Nat. Mus. Vict.* **36**, 63–126.

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STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS OF THE BILLY CREEK FORMATION (CAMBRIAN), EAST OF THE FLINDERS RANGES, SOUTH AUSTRALIA

BY P. S. MOORE

Summary

Two new members (the Coads Hill Member and the Erudina Siltsone Member) are defined in the Billy Creek Formation at Reaphook Hill. The Coads Member consists of a complex sequence of shale, sandstone, carbonate and tuff which was deposited mainly in a shallow marine environment. The overlying Erudina Siltstone Member consists of a silty and sandy redbed sequence with minor dolomite and was deposited on tidal mudflats during a period of regression. A tentative correlation of the Billy Creek Formation between Reaphook Hill and the type section in the Wirrealpa Basin is suggested. The Billy Creek Formation also occurs in the Yalkalpo 2 well, east of Lake Frome, where it comprises mainly green shales and sandstones. Deposition most probably occurred in a relatively open marine environment, which suggests that the Arrowie Basin extended for a considerable distance east of the present Flinders Ranges in the late Early Cambrian. The Billy Creek Formation in the Lake Frome wells Nos 1 and 2, south of Lake Frome, considts of shaly and silty redbeds with common anhydrite, and was deposited on high tidal mudflats laterally adjacent to detaic sediments of the Eregunda Sandstone Member.

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Summary

MOORE, P. S. (1980) Stratigraphy and depositional environments of the Billy Creek Formation (Cambrian), east of the Flinders Ranges, South Australia. *Trans. R. Soc. S. Aust.* **104**(5), 117-132, 28 November, 1980.

Two new members (the Coads Hill Member and the Erudina Siltstone Member) are defined in the Billy Creek Formation at Reaphook Hill. The Coads Hill Member consists of a complex sequence of shale, sandstone, carbonate and tuff which was deposited mainly in a shallow marine environment. The overlying Erudina Siltstone Member consists of a silty and sandy redbed sequence with minor dolomite and was deposited on tidal mudflats during a period of regression. A tentative correlation of the Billy Creek Formation between Reaphook Hill and the type section in the Wirrealpa Basin is suggested. The Billy Creek Formation also occurs in the Yalkalpo 2 well, east of Lake Frome, where it comprises mainly green shales and sandstones. Deposition most probably occurred in a relatively open marine environment, which suggests that the Arrowie Basin extended for a considerable distance east of the present Flinders Ranges in the late Early Cambrian. The Billy Creek Formation in the Lake Frome wells Nos 1 and 2, south of Lake Frome, consists of shaly and silty redbeds with common anhydrite, and was deposited on high tidal mudflats laterally adjacent to detaic sediments of the Eregunda Sandstone Member.

Introduction

The Billy Creek Formation consists of an Early to Middle Cambrian, predominantly redbed sequence of shale, siltstone and sandstone, with minor limestone, dolomite and tuff. It crops out sporadically throughout the central and northern Flinders Ranges of S.A., and has been identified in the subsurface below the Cainozoic and Mesozoic of the L. Frome region (Fig. 1).

The Billy Creek Formation was formally defined by Daily (1956). Outcrops in the central and northern Flinders Ranges have recently been subdivided into three members by Moore (1979b), after redefinition of the status of the Edeowie Limestone Member (Moore 1979a). However, these three members are not recognised at Reaphook Hill or in the subsurface occurrences to the east of the Flinders Ranges, due to the very individual nature of the sequences. This paper discusses the stratigraphy and depositional environments of the Billy Creek Formation at Reaphook Hill, and also briefly discusses the subsurface data, gathered primarily from the Yalkalpo 2 borecore, to the east of L. Frome.

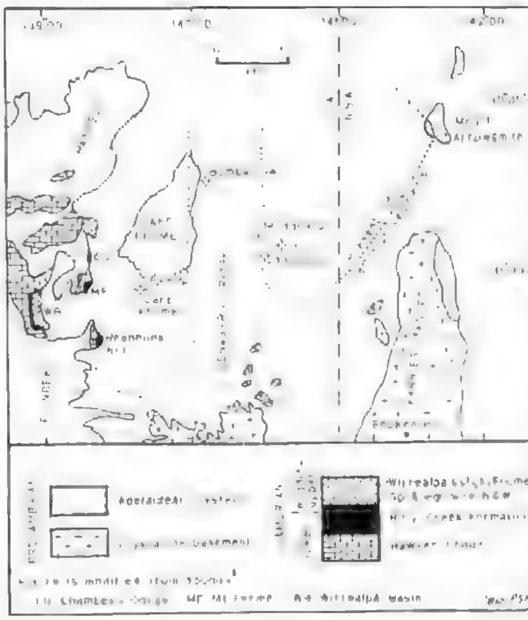


Fig. 1. Outcrop locality map, eastern Flinders Ranges and L. Frome Embayment.

The Reaphook Hill Outcrop

The Billy Creek Formation at Reaphook Hill is subdivided into two members, herein termed the Coads Hill Member and the Erudina Siltstone Member (Fig. 2). The lower sandy portion of the sequence (the Coads Hill Member) was originally considered to be part of the Hawker Group, comprising Bunkers Sandstone equivalent and Oraparinna Shale (Dalgarno & Johnson 1963). However, Dalgarno (1964) recognised tuffaceous and red

* Delhi Petroleum Pty Ltd, 33 King William St, Adelaide, S. Aust. 5000

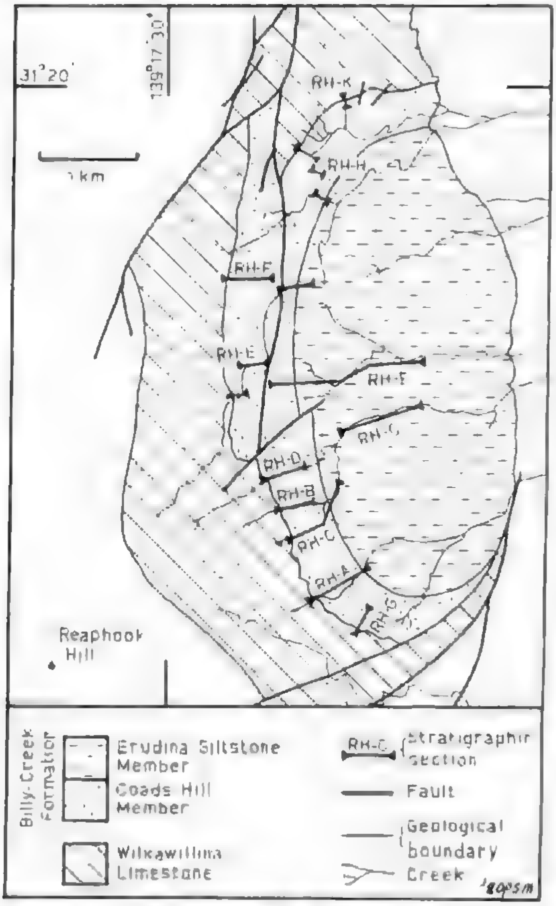


Fig. 2. Outcrop map and location of measured stratigraphic sections, Billy Creek Formation, Reaphook Hill.

silty intervals in the sequence, and redefined it as part of the Billy Creek Formation, as shown on the PARACHILNA 1:250 000 geological sheet (Dalgarno & Johnson 1966). The upper part of the Billy Creek Formation at Reaphook Hill (the Erudina Siltstone Member) is dominated by silty redbeds, with minor dolomitic and sandy intervals.

The Reaphook Hill region was mapped in detail in 1971 by Gaunt[1] and Gehling[2]. Their discovery of Emuellid trilobites in the lower portion of the Billy Creek Formation is of particular interest and the author is indebted to these two authors, whose work provides the basis of the subdivisions presented below.

[1] Gaunt, G. F. M. (1971) The geology of the Kempes Bore area, eastern Flinders Ranges. B.Sc. (Hons.) thesis, University of Adelaide (unpublished).

[2] Gehling, J. G. (1971) The geology of the Reaphook Hill area, Flinders Ranges, South Australia. B.Sc. (Hons) thesis, University of Adelaide (unpublished).

Stratigraphy of the Coads Hill Member

Introduction

The lower part of the Billy Creek Formation at Reaphook Hill comprises a sequence of interbedded, fine to medium-grained, pale brown sandstone, dark grey limestone, and minor red and green shale and shaly siltstone. Interbeds of calcareous shale, shaly limestone, dolomite and tuff occur in some units, and a limestone-boulder conglomerate occurs at the base of the sequence in the northern outcrops (Fig. 3). The sequence is herein termed the Coads Hill Member. The name is derived from "Coads Hill" which is located approximately 7 km W of Reaphook Hill. Section RH-C is chosen as the type section (Fig. 4).

The base of the Coads Hill Member

In the north of the Reaphook Hill region, the basal 6 m of the Coads Hill Member comprise boulder conglomerate, with clasts of limestone up to 30 cm across. The conglomerate was mapped as part of the underlying Hawker Group by Gehling[2], however it rests sharply and unconformably on pale grey, fenestral and oolitic Wilkawillina Limestone. Further south, calcareous sandstones and siltstones of the Coads Hill Member rest disconformably on the Wilkawillina Limestone (Figs 3 & 5a). A pisolitic calcrete horizon, 5–20 cm thick, caps the disconformity surface.

Internal Stratigraphy

The Coads Hill Member is divided into nine units (Fig. 3), which are described below. Units B to G are essentially the same as units recognised by Gaunt[1] and Gehling[2].

Unit A is the basal unit of the Coads Hill Member in the north of the Reaphook Hill region. It comprises cobble to boulder conglomerate, with clasts of pale grey, micritic, fenestral and oolitic limestone and dolomitic limestone, up to 30 cm across. The conglomerate has a closed fabric, with the matrix comprising medium to very coarse sand-sized quartz and minor carbonate. Clasts are generally subangular to subrounded. Some are fossiliferous, containing unidentified fragments of trilobites and other shelly debris. The clast lithologies are very similar to underlying Wilkawillina Limestone.

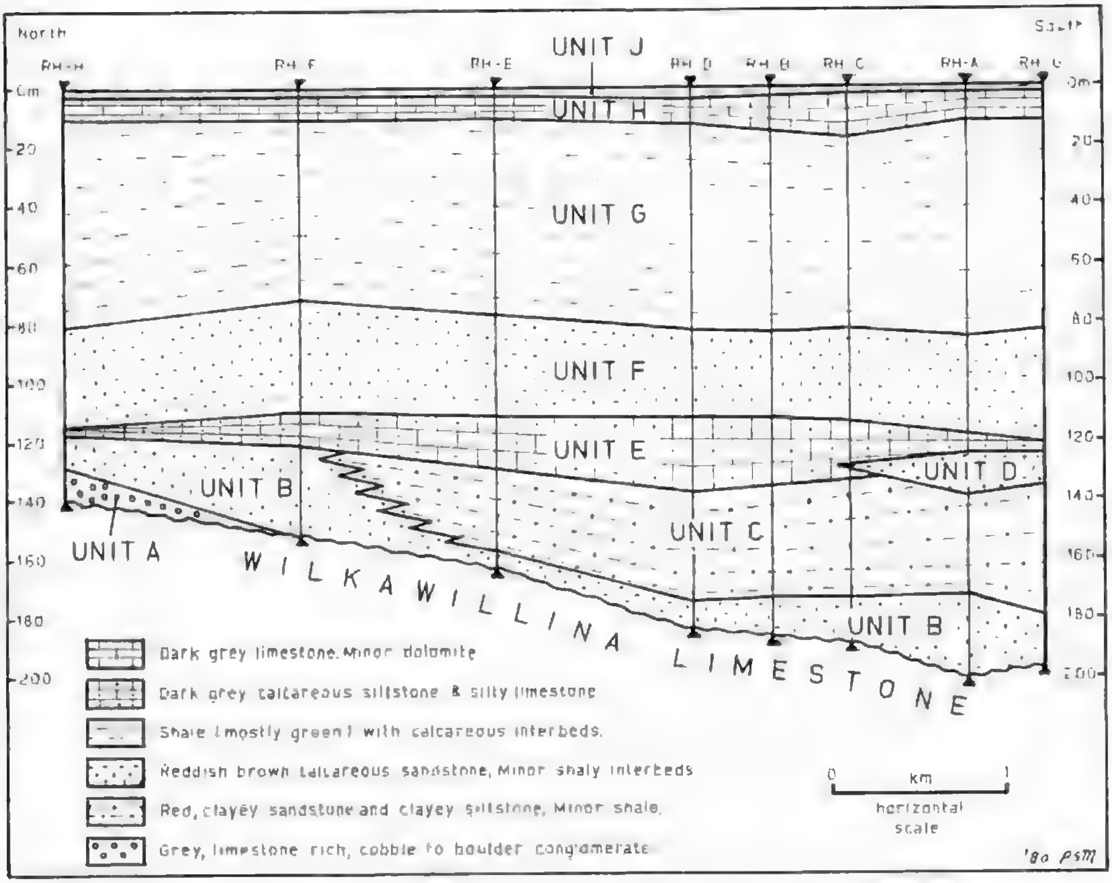


Fig. 3. Stratigraphy of Coads Hill Member, Billy Creek Formation, Reaphook Hill.

Unit B is the basal unit of the Coads Hill Member in the south of the Reaphook Hill region, and conformably overlies Unit A in the north. It comprises pale red to reddish brown, fine to medium grained, feldspathic sandstone (Fig. 5b). Interbeds of greyish red shale and shaly siltstone are common in the upper portions of the unit. The sequence is evenly bedded to ripple laminated on the scale 3–15 cm. Small to medium scale tabular cross-stratification is common in the thicker sections. Desiccation cracks, symmetrical ripples, mudstone intraclasts and small scour-and-fill structures are common throughout the unit and worm burrows, interference ripples and pebbly horizons occur in some outcrops. A 5 cm thick, bright green tuffaceous interval with devitrified shards occurs in the middle portion of Section RH-H, in the north of the area.

Unit C comprises greyish red, very poorly sorted, shaly siltstone to silty sandstone, with minor granule and pebble-rich bands (Fig. 5c). Ripple laminated interbeds of moderately sorted, reddish brown sandstone, 5–20 cm thick, are common in the lower portion of the sequence, and define a passage from Unit B. Mudstone intraclasts and desiccation cracks are abundant (Fig. 5d). Bedding is poorly defined in most of the unit, although the upper few metres are dominated by red silty shale with well developed, even lamination.

Unit D comprises a thin tongue of pale yellowish brown, moderately sorted to well sorted, feldspathic sandstone (Fig 5e) which crops out in the southern portion of the area, where it rests conformably on Unit C (Fig. 3). The sandstones are evenly bedded on the scale of 3–12 cm with some poorly defined ripple laminations and rare symmetrical ripple marks. Large scale cross-stratification is absent. A thin, bright olive green tuffaceous interval crops out in the upper portion of the unit in

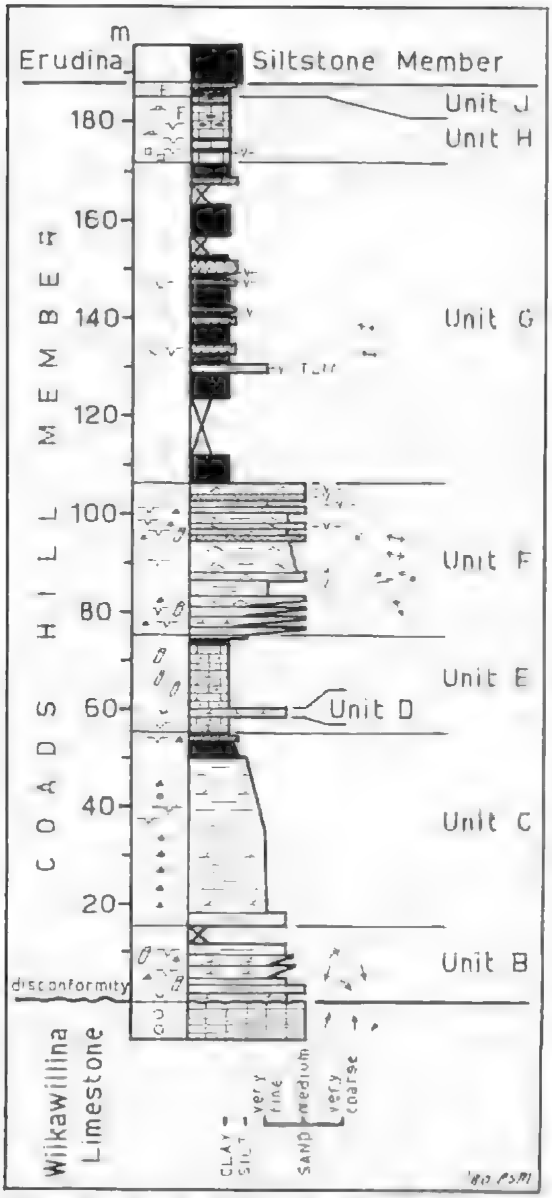


Fig. 4. Type section (RH–C) of Coads Hill Member, Billy Creek Formation. See legend Fig. 8.

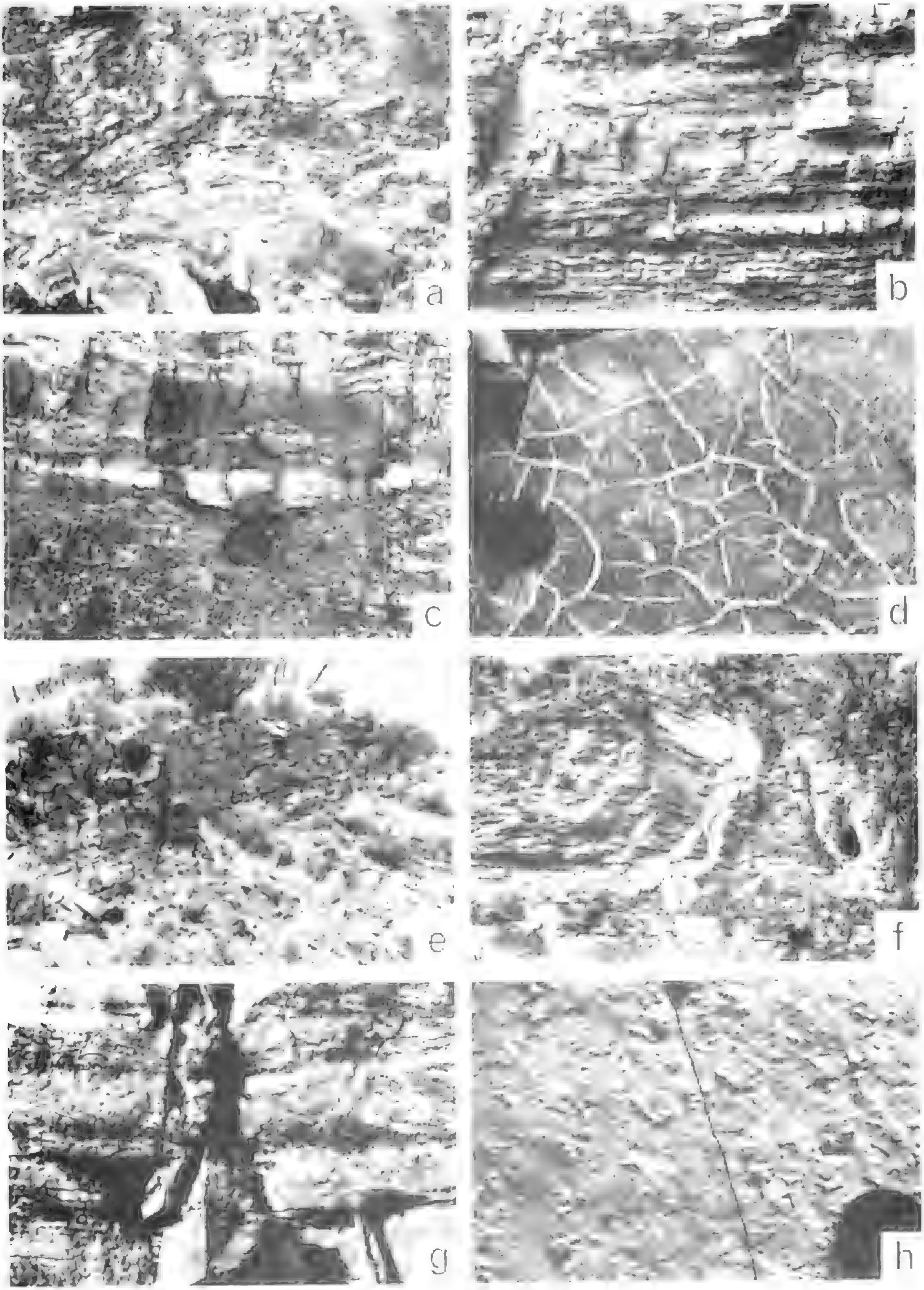
Section RH-G. Green shale intraclasts and incipient shrinkage cracks are abundant throughout the sequence.

Unit E is a sequence of dark grey, foetid, silty limestone, calcareous shale and siltstone (Fig. 5f). In the thicker sections, a well-developed sequence ranges from buff-coloured stromatolitic dolomite at the base, through burrow-mottled shaly grey limestone and calcareous shale in the lower portion, into dark grey foetid limestone in the middle and upper portion. Much of Unit E is bioturbated, and desiccation cracks occur sporadically throughout the sequence.

Unit F comprises pale reddish brown to brown, fine to medium-grained, feldspathic sandstone. Interbeds of shale and siltstone are common in some outcrops. Several bright olive green tuffaceous intervals up to 30 cm in thickness are present, and are particularly prominent in the upper shaly portion of the unit. The sequence is generally evenly bedded to ripple laminated. However, medium scale tabular cross-stratification is common in the northern outcrops (Fig. 5g). Mud-cracks, quartz-lined geodes, oscillation ripples, current ripples, mudstone intraclasts, small scour-and-fill structures and worm burrows are common throughout. Interference ripples occur in some outcrops. In the north, the sandstones are relatively mature, and are partly cemented by calcite. Further south, the sandstones are interbedded with red shale and siltstone, and contain rare pebble beds.

Unit G comprises green shale and calcareous shale, with common, thin interbeds of shaly, dolomitic limestone and dolomite. Minor red shaly intervals occur in the lower portion of the unit, especially in the south. Bright olive green tuffaceous interbeds, rarely up to 1.4 m thick, are common throughout the sequence. Units are generally evenly laminated, although rare asymmetrical ripple marks are

Fig. 5: a. Red shaly siltstones and sandstones of Unit B, Coads Hill Member, draping irregular disconformity surface at top of Wilkawillina Limestone. Hammer: 31 cm long. Location: Section RH–C, Reaphook Hill. b. Evenly bedded to cross-stratified reddish brown siltstones and sandstones of Unit B, Coads Hill Member. Hammer: 31 cm long. Location: Section RH–D, Reaphook Hill. c. Small sandy channel in very poorly sorted red shaly siltstone of Unit C, Coads Hill Member. Scale: 54 mm diameter. Location: Section RH–A, Reaphook Hill. d. Incipient shrinkage cracks in fine red sandstone of Unit D, Coads Hill Member. Scale: 54 mm diameter. e. Typical outcrop of Unit D, Coads Hill Member, showing prominent ridge of evenly bedded and rarely ripple laminated, medium grained sandstone. Location: Section RH–A, Reaphook Hill. f. Prominent ridge of grey, foetid, silty limestone and calcareous siltstone. Basal unit is lighter coloured and dolomitic. Location: Unit E, Coads Hill Member. Section RH–E, Reaphook Hill. g. Cross-stratification in reddish brown calcareous sandstones of Unit F, Coads Hill Member. Note abundance of mudstone intraclasts concentrated on foresets of cross-strata. Location: Section RH–F, Reaphook Hill. h. Basal view of yellowish brown shaly dolomite containing abundant halite casts. Scale: 54 mm diameter. Location: Unit H, Coads Hill Member. Section RH–C, Reaphook Hill.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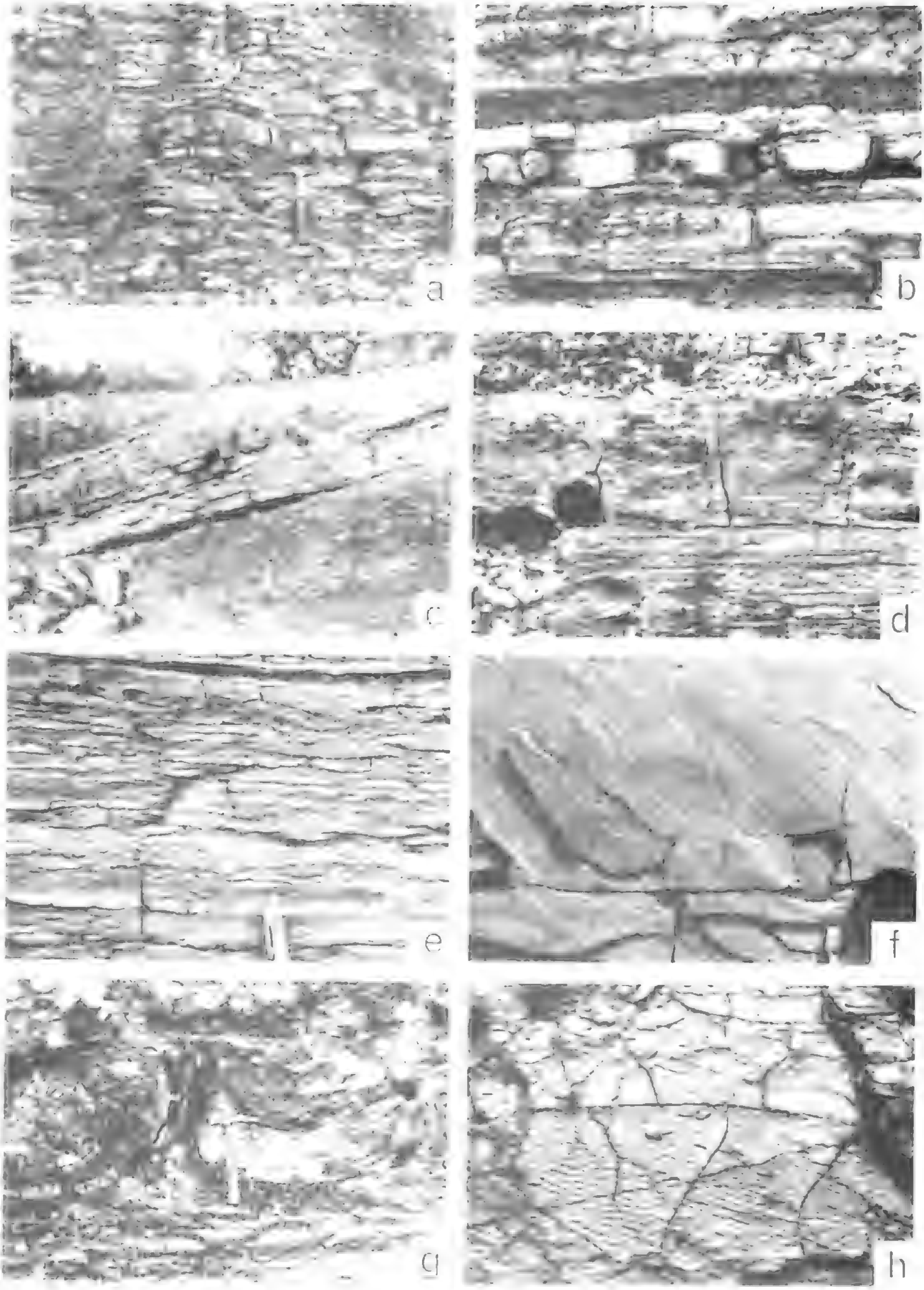
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present in silty intervals in the south. Desiccation cracks and halite imprints are common in some sections (Fig. 5h). Abundant trilobites (*Balcoracania dailyi* Pocock) and rare, unidentified brachiopod fragments are present in green shale overlying dolomite, approximately 43 m above the base of Unit G in Section RH-A.

Unit H comprises a sequence dominated by dark grey, foetid limestone. Interbeds of shaly limestone are common, and much of the sequence has a well-developed nodular (lensoid) texture (Fig. 6a). The upper and lower portions of Unit H are shaly and dolomitic, and contain stromatolites (Fig. 6b), desiccation cracks and minor halite imprints. Unidentified trilobite fragments are uncommon, but have been recorded from the middle to upper portion of the sequence

Unit J comprises approximately 3 m of evenly laminated, khaki shale and fine siltstone, with minor carbonate bands and nodules. The trilobite *B. dailyi* is abundant in the basal portion, and is associated with rare, unidentified brachiopod fragments. A 0.5 m thick peloidal and algal, mottled limestone forms a prominent marker at the top of Unit J.

Age and Palaeontology

Trilobite tracks, worm burrows and molluscan trails occur sporadically throughout the Coads Hill Member. At least one type of trace fossil is present in every unit, with the exception of Unit C. Emuellid trilobites were first discovered by Gaunt[1] and Gehling[2] in what is now defined as the basal portion of Unit J of the Coads Hill Member. B. Daily (pers. com *in* Gehling[2], p. 16) identified the trilobites as *B. dailyi*. The species also occurs in the upper portion of the White Point Conglomerate on Kangaroo Island, where it has been assigned a late Early Cambrian age (Pocock 1970).

Depositional environment of the Coads Hill Member

Following deposition of shallow marine and supratidal carbonates of the uppermost Hawker Group, the Adelaide "Geosyncline" in the vicinity of Reaphook Hill was uplifted and the Hawker Group eroded. Deposition of the Coads Hill Member of the Billy Creek Formation commenced when the area once again became submerged. Limestone boulders eroded from nearby areas were deposited in a nearshore marine environment in the north (Unit A) while a thin calcrete profile developed on the land surface to the south. Subsequently, a sequence of shallow marine to intertidal, calcareous sandstones (Unit B) spread over the area.

Red, shaly and pebbly sandstones (Unit C) are considered to be non-marine in origin, because of a lack of fossils and their traces, and also the extremely poor sediment-sorting. Thus, a likely environment of deposition for Unit C is a muddy alluvial plain, and its presence in the Reaphook Hill area indicates a period of marked local regression.

The origin of the lower, foetid, shaly carbonate (Unit E) is of particular interest, since it is underlain by redbeds which are probably non-marine (Unit C), and overlain by shallow marine to intertidal calcareous sandstones (Unit F). The lamination and fine grain-size of Unit E indicates deposition from suspension in a low energy environment. The lack of body fossils suggests restricted marine conditions, while the presence of laminated dolomicrite.

Fig. 6. a. Nodular (lensoid), shaly limestones of Unit H, Coads Hill Member. Hammer: 31 cm long. Location: Section RH-H, Reaphook Hill. b. Interbedded grey calcareous shale and shaly limestone of Unit H, Coads Hill Member. Note presence of weathered-out stromatolites in centre of photo. Stromatolite elongation perpendicular to outcrop. Hammer: 31 cm long. Location: Section RH-F, Reaphook Hill. c. Large scale shaly-carbonate cycle in Unit A, Erudina Siltstone Member. Red shales pass gradationally through green shales and greyish green calcareous shales into pale grey to buff-coloured dolomitic limestone. Rapid regression back into red shale is typical of cycles. Hammer. 31 cm long. Location: Section RH-C, Reaphook Hill. d. Thin unit of yellowish brown shaly dolomite with wavy stromatolitic laminations in middle of asymmetrical shale-dolomite-shale cycle. Scale. 54 mm diameter. Location: Unit A, Erudina Siltstone Member, Section RH-C, Reaphook Hill. e. Wavy and lenticular bedding in shaly siltstones of Unit D, Erudina Siltstone Member. Mudflake intraclasts are common. Location. Section RH-C, Reaphook Hill. f. Current lineated red micaceous sandstones of Unit C. Erudina Siltstone Member. Scale: 54 mm diameter. Location: Section RH-C. Reaphook Hill. g. Large load structures with subvertical symmetry, probably associated with dewatering. Hammer: 31 cm long. Location: Unit C, Erudina Siltstone Member, Section RH-C, Reaphook Hill. h. Symmetrical wave ripples in coarse red siltstone. Bedding surface dissected by large, polygonal desiccation cracks infilled with red mudstone. Lenscap scale: 54 mm diameter. Location: Section RH-C. Reaphook Hill.

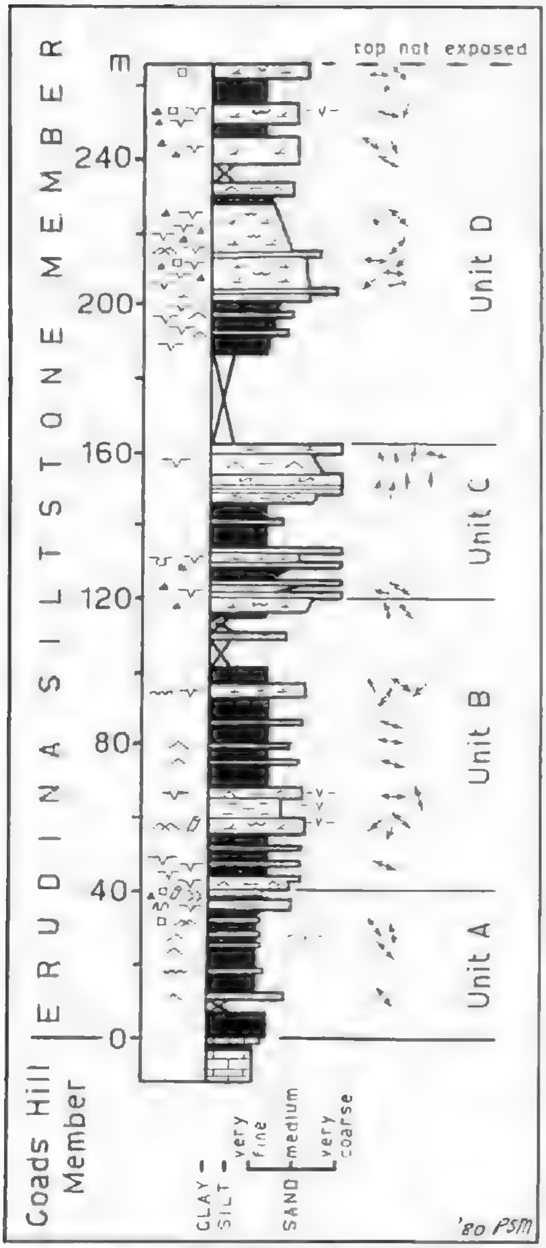

Fig. 7. Type section (RH-C) of Erudina Siltstone Member, Billy Creek Formation, Reaphook Hill. See legend Fig. 8.

stromatolites and desiccation cracks indicates that at least part of the sequence was deposited in shallow water. The foetid odour and dark colour of the bulk of Unit E is evidence for restricted circulation and poor oxygenation, such as occurs in a restricted embayment or lagoon. Unit D sandstones, which are laterally equivalent to Unit E, probably represent deposition in a littoral environment

Shallow marine calcareous sandstones of Unit F pass gradationally into micaceous shales of Unit G. The shales contain arthropod tracks and dolomitic intervals, and thus were deposited on subtidal to intertidal mudflats subject to frequent marine inundation and reducing conditions.

The upper, dark, foetid limestone (Unit H) is somewhat different from the lower one, for it contains minimal terrigenous clastic detritus, and is relatively uniform in thickness and character throughout the area of outcrop. Thus, Unit H probably accumulated in a semi-restricted, very shallow marine environment, subject to only minor fine-grained terrigenous influx. A connection with the open sea is inferred from the presence of trilobites, however the water was generally quite shallow, as indicated by sporadic desiccation cracks and stromatolitic intervals, and was also poorly oxygenated, as indicated by the high organic content of the limestone, its dark colour and its foetid odour.

The thin sequence of green fossiliferous shale (Unit J) which occurs at the top of the Coads Hill Member indicates a period of fine-grained clastic deposition in a relatively open, shallow marine environment. A rapid decrease in fossil fragments towards the top of the unit indicates progressive restriction and shallowing of the basin, prior to the deposition of the Erudina Siltstone Member.

Stratigraphy of the Erudina Siltstone Member

Introduction

The upper portion of the Billy Creek Formation at Reaphook Hill comprises a sequence of greyish red siltstones and silty shales, with minor dolomitic, tuffaceous and sandy interbeds. The sequence is herein termed the Erudina Siltstone Member. The name is derived from the Erudina homestead, located approximately 15 km SE of Reaphook Hill.

The Erudina Siltstone Member crops out in the central portion of a small basinal structure at Reaphook Hill (Fig. 2), where it conformably overlies the Coads Hill Member. Maximum measured thickness is 270 m in Section RH-C, however the original thickness is unknown since the upper portion of the member has been removed by erosion. Section RH-C is chosen as the type section (Fig. 7). The member is clearly divisible into four units, described below.

Internal Stratigraphy

The basal unit of the Erudina Siltstone Member (Unit A) comprises a fine-grained sequence of cyclically interbedded silty shale and carbonate. Half-cycles, from red shale through pale greyish green shale into buff-coloured dolomite or dolomitic limestone are typical (Fig. 6c). The carbonates are evenly laminated to wavy laminated, with rare desiccation cracks, halite imprints and stromatolites (Fig. 6d). Shaly and silty clastic intervals commonly contain desiccation cracks and symmetrical ripple marks. Raindrop imprints, calcareous algal mats, halite imprints, worm burrows and arthropod tracks and trails are rare.

Unit B comprises approximately 80 m of red shale, silty shale and shaly siltstone, with minor sandy interbeds. The sequence is evenly laminated, with minor wavy bedding (Fig. 6e) and ripple lamination in the coarser units. Symmetrical and near-symmetrical (wave-formed) ripples predominate, although highly asymmetrical (current formed) interference ripples, and flat-topped ripples also occur. Desiccation cracks and mudstone intraclasts are abundant, whereas halite casts and small load structures are relatively uncommon. The redbeds are weakly calcareous, and crenulated, carbonate-rich algal mats occur in a few localities. Arthropod tracks and bioturbated intervals are rare. Pink, silty, tuffaceous units are also rare.

Unit C comprises a 40 m thick sequence of interbedded shaly, silty, and sandy redbeds. Coarsening-upward cycles are present, and vary in thickness from a few metres to twenty metres. The silty units are wavy bedded to ripple laminated, and are commonly associated with desiccation cracks, mudstone intraclasts, trilobite tracks, worm burrows, and symmetrical interference and current ripples. Sandy intervals are commonly ripple laminated, with rib-and-furrow structures on the upper surface. Thicker intervals in the upper portion of Unit C are horizontally laminated, with well-developed current lineation (Fig. 6f), current crescents and rare bounce marks. Trilobite tracks and scratch marks are common in the sandy units, which also contain desiccation cracks, mudstone intraclasts, load structures (Fig. 6g), rare worm burrows and molluscan trails.

Unit D comprises a 100 m thick sequence of interbedded red silty shale, shaly siltstone and siltstone very similar in character to Unit B. Silty intervals are wavy bedded, flaser bedded, and ripple laminated, and both symmetrical and asymmetrical ripple marks are abundant throughout the sequence (Fig. 6h). Desiccation cracks, halite imprints and mudstone intraclasts are common. A few units contain interference and flat-topped ripples.

Palaeontology

Worm burrows, molluscan trails and tracks attributed to trilobites occur sporadically throughout the Erudina Siltstone Member. The only body fossils found to date are tiny (1–2 mm long) carbonaceous imprints in green shale in the lower portion of Unit A. These are interpreted as fossil annelids.

Depositional environment of the Erudina Siltstone Member

The Erudina Siltstone Member consists of four units which are distinguished primarily on the basis of grain-size. Unit A is fine-grained, comprising red shale with dolomitic interbeds. The shales were deposited in an oxidising environment on muddy tidal flats probably as a response to mild tectonism (the Kangarooian Movements of Daily & Forbes 1969). Carbonate mudstones accumulated in the lower intertidal to subtidal environment during periods of relative tectonic quiescence. Cycles in the shale-carbonate sequence of Unit A are attributed to local transgressions and regressions, and reflect the unstable nature of the basin of deposition and adjacent source areas during this period.

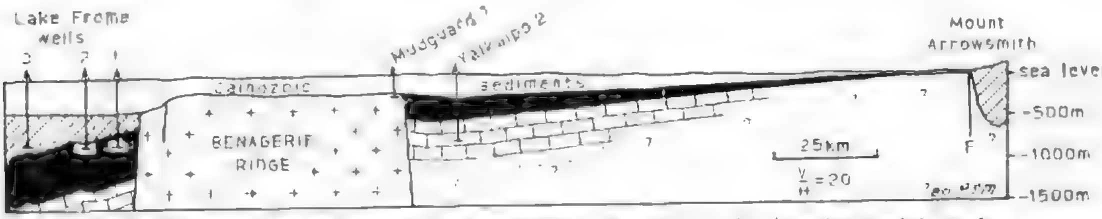

Fig 8 Simplified cross-section, eastern Arrowie Basin. See Fig. 1 for location and legend.

Unit B was deposited in response to increased tectonic activity, whereby red shales and siltstones were deposited on muddy intertidal flats and in the shallow subtidal environment. The rate of sedimentation was sufficient to obscure carbonate accumulation and instead, a sequence of fine-grained redbeds with distinctive tidal stratification (cf. Reineck & Wunderlich 1968) was developed.

During the deposition of Unit C, sand was carried into the basin, forming coarsening-upward cycles of redbed clastics. The cycles are attributed to pulses of tectonism which reached a peak late in the history of deposition of Unit C. Unit D represents a return to somewhat more stable conditions, as experienced during the evolution of Unit B. Fine-grained, shaly and silty redbeds dominate the sequence, which contains an abundance of poorly defined simple and wavy flaser bedding.

Subsurface distribution of the Billy Creek Formation

The Billy Creek Formation occurs subsurface in the Arrowie Basin to the east of the Flinders Ranges, generally below the Mesozoic of the L. Frome Embayment and in some places below the Cainozoic of the Tarkarooloo Basin[3]. The present limits of the Cambrian basin in this region, as suggested by Youngs[4], are shown in Figure 1. A simplified cross-section is presented in Figure 8.

As shown in Figure 8, the Billy Creek Formation was intersected by L. Frome stratigraphic wells Nos. 1 & 2[7] and SADME Yalkalpo No. 2[8]. The EAR uranium exploration holes south of L. Frome mostly ended in weathered and leached, shaly redbeds[9], many of which probably belong to the Billy Creek Formation. An interpretive subcrop map for the area south of L. Frome is presented in Figure 9, based on the author's own evaluation of cores and cuttings.

SADM Yalkalpo No. 2

The Billy Creek Formation in Yalkalpo 2 comprises red and green shales and siltstones, with common reddish brown sandy intervals[8]. Approximately 265 m of strata attributed to the lower portion of the Billy Creek Formation were intersected (Fig. 10). The original total thickness of the formation at this locality is unknown, since the upper portion of the sequence has been removed by post-Cambrian, pre-Cretaceous erosion (Youngs 1978).

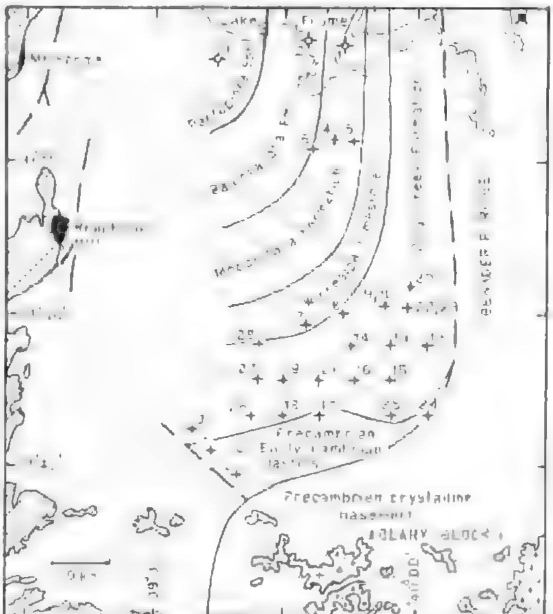

Fig. 9. Interpretive pre-Cretaceous subcrop map, south of L. Frome. Evidence suggests only thin pre-Billy Creek Formation clastic sequence in this area, with probable faulting against Olary Block.

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[3] Osborne[5] first introduced the term "Frome Embayment", defining it as a synclinal basin bounded by the Flinders and Barrier Ranges. As presently defined (Wopfner 1969), the term "Frome Embayment" refers only to the Mesozoic sedimentary basin. The overlying Cainozoic sediments of the Tarkarooloo Basin[6] are unconformable on the Cretaceous and relate to a different cycle of events.

[4] Youngs, B. C. (1969) Bumbarlow 1—well completion report. S. Aust. Dept Mines & Energy (unpublished).

[5] Osborne, N. (1945) Report on oil and gas possibilities of the Frome Embayment, New South Wales and South Australia, for Zinc Corp. Ltd. S. Aust. Dept Mines & Energy open file report (unpublished).

[6] Callen, R. A. (1976) 1:250 000 geological series explanatory notes, FROME, South Australia. S. Aust. Dept. Mines & Energy Rept 76/27 (unpublished).

[7] Delhi Australia Petroleum Ltd. and Santos Ltd (1969) Well completion report, Lake Frome 1, 2 & 3. S. Aust. Dept Mines & Energy open file envelope 968 (unpublished).

[8] Youngs, B. C. (1977) Mudguard 1 and Yalkalpo 2—well completion reports. S. Aust. Dept Mines & Energy 77/66 (unpublished).

A moderate to high sand content, and a dominance of non-red sediments differentiates the Yalkalpo 2 sequence from most other known occurrences of the Billy Creek Formation, and the absence of carbonates differentiates it from the Coads Hill Member. Thus, the Yalkalpo 2 sequence between 258 m and 523 m depth is defined as Billy Creek Formation *sensu stricto*.

Fine-grained intervals dominate the sequence, particularly in the upper portions. A facies spectrum is present, from ripple laminated fine-grained sandstone with green shale flasers, through wavy flaser and lenticular bedded units (cf. Reineck & Wunderlich 1968, and Reineck & Singh 1975) into evenly laminated green shale (Fig. 10). Redbeds comprise only about 30% of the fine-grained association and generally consists of wavy bedded to evenly laminated shales and coarse siltstones. Worm burrows are common, and occur mainly in the green intervals. Molluscan trails and tracks attributed to trilobites occur both in red and green coloured sediment, although they are slightly more common in the latter. Desiccation cracks are abundant in many of the red shale intervals, and in rare cases are associated with halite imprints, and patches and veins of anhydrite. Cyclic sedimentation between red and green intervals, each with its characteristic set of sedimentary structures and organic markings, is a feature of the middle portion of the sequence (especially in the intervals 380–450 m).

Coarse-grained intervals comprise reddish brown to yellowish brown, very fine to medium-grained feldspathic sandstone. In some cases (e.g. at 497 m) the sandstones rest sharply on fine-grained sediments, and contain abundant mudstone intraclasts in the basal portions of the units. More commonly however, the sandstones occur at the top of coarsening-upward sequences. They are generally evenly bedded, with abundant soft-sediment deformation in the thicker units. Some of the thinner sandy units are ripple laminated, and green and minor red flasers may be present. Mudstone intraclasts are common. A feature of the sandy intervals is the absence of well-developed large-scale cross-stratification.

Delhi-Santos Lake Frome Stratigraphic Wells

The Billy Creek Formation *sensu stricto* has been identified from the L. Frome wells Nos. 1 and 2 by Daily[10]. This identification is confirmed here. Only the upper part of the Billy Creek Formation was penetrated[7], and this interval is considered to be the approximate lateral equivalent of the Eregunda Sandstone Member in the central and northern Flinders Ranges (Moore 1979b). However, the interval is not appreciably sandy and thus should not be referred to as the Eregunda Sandstone Member. Rather, it is considered only as "Billy Creek Formation".

A log of the Billy Creek Formation as intersected in L. Frome No. 1 is presented in Figure 11. The sequence is rather homogenous, comprising fine-grained redbeds with minor green intervals. A transition into the the overlying Wirrealpa Limestone is indicated. Cuttings were sampled at 10 feet intervals and cores 5–7 were taken in the Billy Creek Formation (Fig. 11).

Examination of cored intervals reveals a spectrum of facies, with increasing silt content, ranging from evenly laminated claystones, through wavy bedded mudstones, into poorly-defined flaser-bedded siltstones. Ripple laminated siltstones devoid of clay laminae are uncommon. Anhydrite and calcite patches, veins and lenses are present in all cored intervals, although they are more common in the finer-grained facies. Secondary reduction, associated with a colour change from red to green, commonly surrounds the anhydrite[11]. Halite imprints occur sporadically throughout the cored sections, and typically occur on rippled bedding surfaces. Desiccation cracks are common. Mudstone intraclasts and rill marks are also common in parts of sequence, particularly in the coarser-grained intervals. Thin, pinkish intervals at 780.3 m and 780.7 m in core 7 of L. Frome No. 1 contain abundant altered, subangular feldspar, and by analogy with outcrops in the Flinders Ranges, are considered to be tuffaceous in origin.

[9] Rudd, E. A. Pty Ltd (1970) Report on investigations, Lake Frome Embayment, S.A. SML's 267 and 268. S. Aust. Dept Mines & Energy open file envelopes 1109 & 1110 (unpublished).

[10] Daily, B. (1969) Remarks on the subsurface stratigraphy and palaeontology of the Delhi-Santos Lake Frome Nos 1–3 Stratigraphic Wells S. Aust. Dept Mines & Energy open file envelope 968 (unpublished).

[11] Moore, P. S. (1979) Stratigraphy and sedimentology of the Billy Creek Formation (Cambrian, Flinders Ranges) and its equivalents on the northeast coast of Kangaroo Island, South Australia. Ph.D. thesis, University of Adelaide (unpublished).

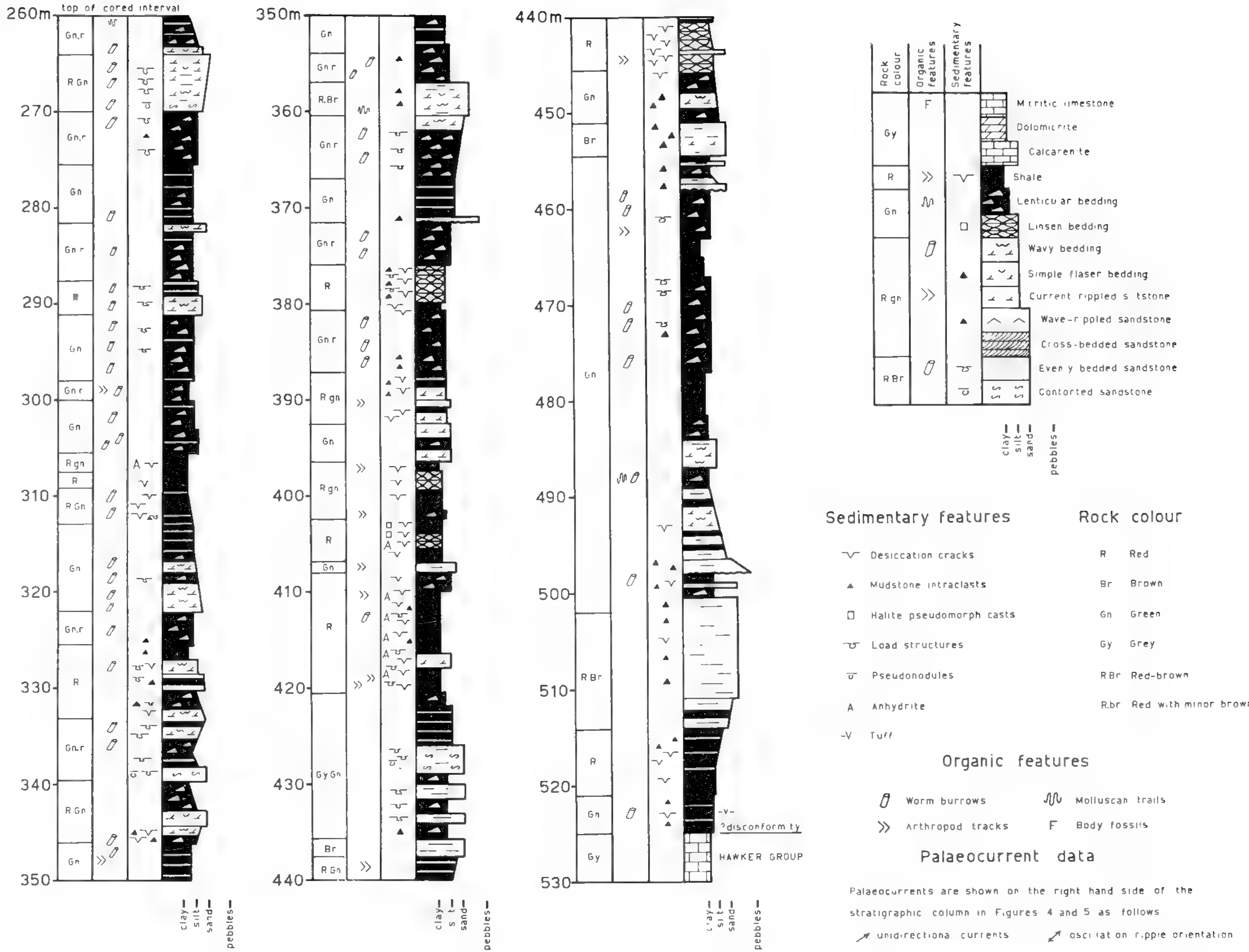


Fig. 10. Stratigraphic log, Billy Creek Formation in Yalkalpo 2, east of L. Frome.

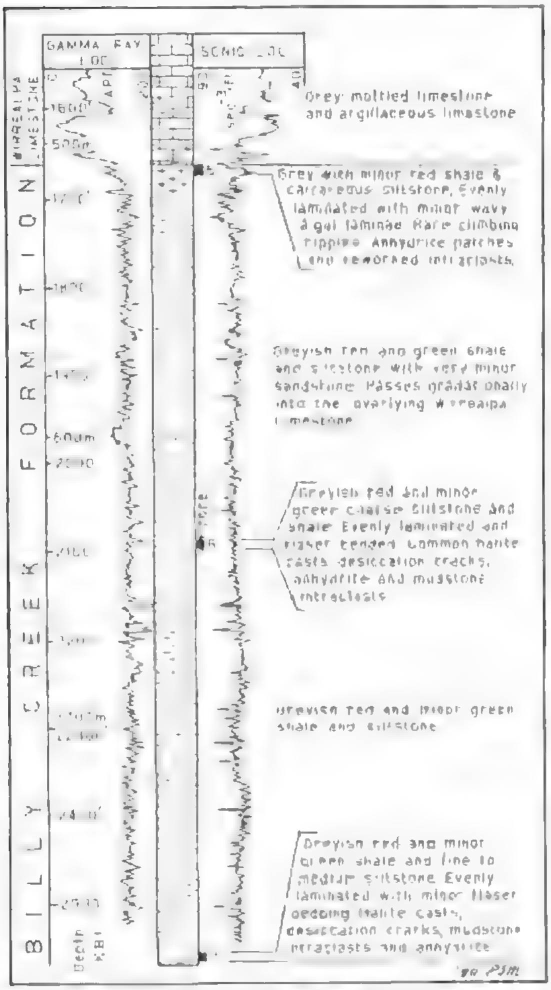


Fig. 11. Stratigraphic log, Billy Creek Formation in L. Frome 1, S of L. Frome.

Tracks attributed to trilobites occur in several of the cores[10], however no body fossils have been found to date.

Internal correlations

The Erudina Siltstone Member at Reaphook Hill is considered to be the approximate lateral equivalent of the Nildottie Siltstone Member in the central Flinders Ranges (Fig. 12). Both members are interpreted as being the result of a major phase of tectonism in the source area which caused basin-wide regression and promoted the development of red-bed facies over a wide area.

Similarities between the underlying Coads Hill Member at Reaphook Hill and the Warragee Member in the central Flinders Ranges support this correlation (Fig. 13). In the Wirrealpa Basin type section, the upper part of the Warragee Member comprises a semi-restricted marine sequence with green shales, several thick dolomite beds, and prominent tuffaceous intervals. A comparable although less-restricted sequence is present in the upper portion of the Coads Hill Member (Units G-J) at Reaphook Hill and a correlation is made on this basis. In particular, Unit H of the Coads Hill Member (an open marine, grey limestone) is considered to pass laterally (shorewards) into a sequence of interbedded dolomites and green calcareous shales in the Wirrealpa Basin (Fig. 13). On the basis of this correlation, it would appear that the strata containing *B. dailyi* at Reaphook are essentially the same age as those containing *B. flindersi* in the Wirrealpa Basin (Fig. 13), despite the appearance of *B. flindersi* in the type section being partly controlled by sedimentological rather than evolutionary factors (Moore 1979b).

Correlation of the Billy Creek Formation between Reaphook Hill and the central Flinders Ranges has been made possible only by the fortunate coexistence of distinctive tuffaceous and calcareous sequences. Either of these features on its own would probably have been insufficient for a satisfactory correlation. It was hoped that a similar method could be employed for the correlation of the Billy Creek Formation between the outcrops of the Flinders Ranges and the subsurface occurrences to the east. Unfortunately, neither thick tuffs nor distinctive calcareous beds were found in the Yalkalpo 2 borecore, and thus the relationship between this sequence and the rest of the Billy Creek Formation remains uncertain. However, since there is no evidence of a regression in the upper portion of the

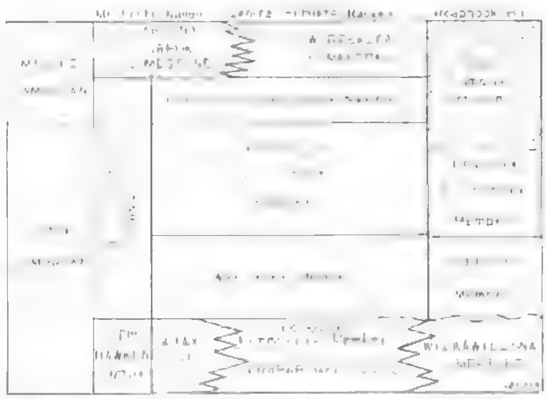
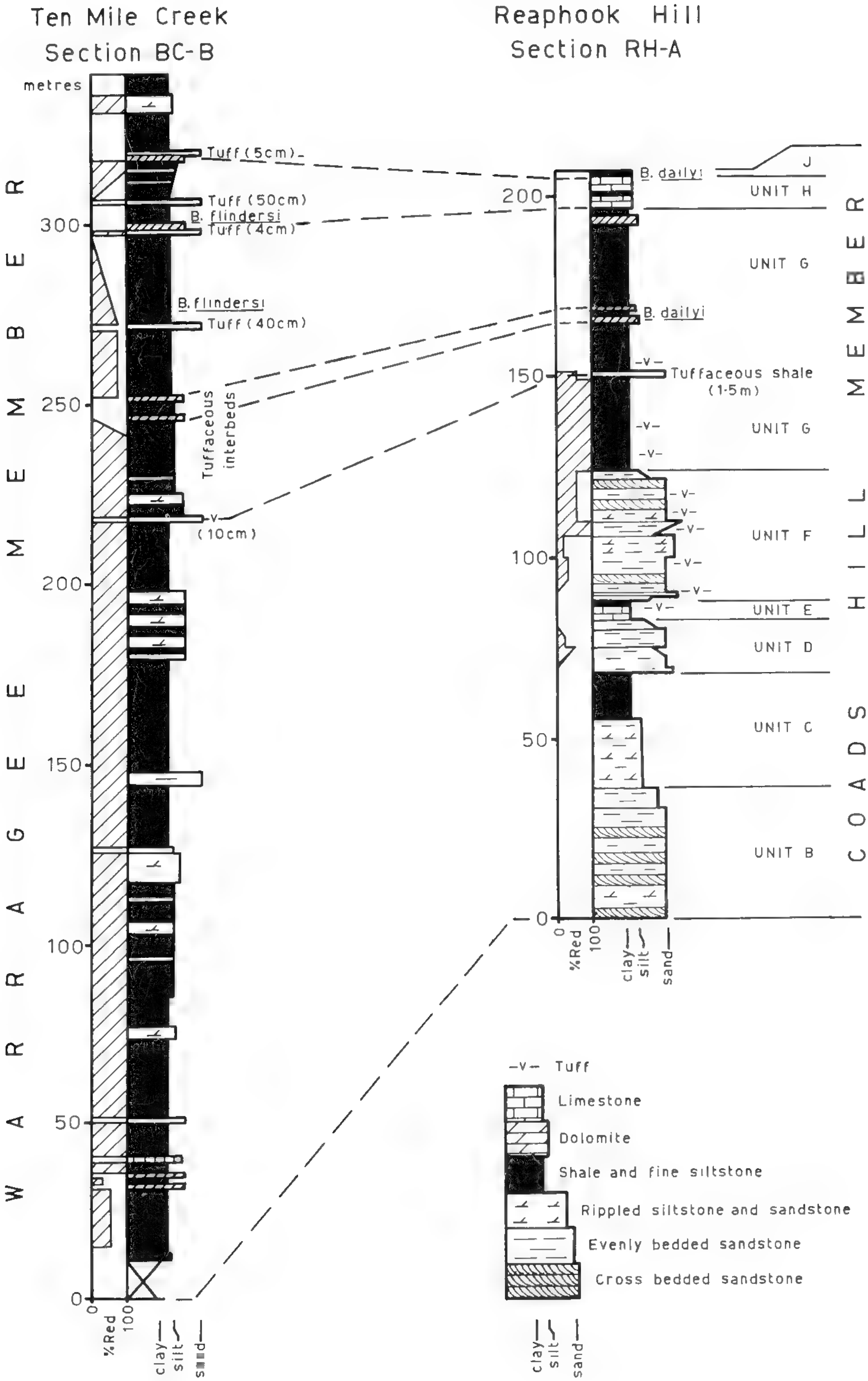


Fig. 12. Stratigraphy of Early to Middle Cambrian Billy Creek Formation.



Ten Mile Creek
Section BC-B
metres
Tuff (5cm)
Tuff (50cm)
B. flindersi
Tuff (4cm)
B. flindersi
Tuff (40cm)
Tuffaceous interbeds
(10cm)
W A R R A G E E M E M B E R
300
250
200
150
100
50
0
%Red
clay
silt
sand
Reaphook Hill
Section RH-A
B. dailyi
J
UNIT H
UNIT G
B. dailyi
Tuffaceous shale (1·5m)
UNIT G
UNIT F
UNIT E
UNIT D
UNIT C
UNIT B
C O A D S H I L L M E M B E R
200
150
100
50
0
Tuff
Limestone
Dolomite
Shale and fine siltstone
Rippled siltstone and sandstone
Evenly bedded sandstone
Cross bedded sandstone

preserved Yalkalpo 2 sequence corresponding with the development of the Nildottie and Erudina Siltstone Members further west, it is likely that the Billy Creek Formation in Yalkalpo 2 is equivalent to the lower-middle and ?upper parts of the Warragee and Coads Hill Members.

On the basis of isopach and palaeocurrent trends, Moore (1979c) considered that the Eregunda Sandstone Member was originally deposited at Reaphook Hill, but has since been removed by erosion. The apparent absence of the Eregunda Sandstone Member in the Delhi-Santos L. Frome wells (Fig. 11) is interpreted as an effect of lateral facies change, with deltaic sandstones passing laterally into supratidal evaporitic mudflats. A comparable Recent example is quoted by Thompson (1968, 1975) from the Gulf of California.

Conclusions

In the northern part of the Adelaide "Geosyncline", initial tectonic activity associated with the Kangarooian Movements (Daily & Forbes 1969) terminated a major phase of Early Cambrian carbonate deposition and promoted the development of a thick sequence of red-beds (the Billy Creek Formation). Five members are defined within the Billy Creek Formation (Moore 1979b and this paper), which crops out in the Flinders Ranges and occurs in the subsurface to the east. During the early stages of deposition of the Billy Creek Formation, a broad muddy tidal flat developed in the west (the Warragee Member) while to the east, a complex stratigraphy (the Coads Hill Member) was evolving. The great variety of facies in the Coads Hill Member emphasises the instability of this eastern region during the late Early Cambrian, although in general this sequence and the laterally equivalent sequence in Yalkalpo 2 were deposited in a more open marine environment than the Warragee Member. Minor volcanic activity, probably in the Mt Wright region of N.S.W., is recorded as thin tuffaceous interbeds in the lower half of the formation.

Further uplifts in the source area released silt and fine sand into the basin, forming the laterally equivalent Nildottie and Erudina Siltstone Members. The red-bed facies of both members were deposited mainly in the intertidal to supratidal zones under the influences of weak wave and current activity, while cyclically interbedded dolomites in the more easterly outcropping Erudina Siltstone Member were probably deposited in sheltered coastal lagoons in the shallow subtidal zone.

Final uplift further increased topographic relief in the source area and a complex of fluvial dominated fan-delta sands (the Eregunda Sandstone Member) prograded across the basin of deposition from the southeast (Moore 1979c). Palaeocurrent and petrographic data indicate that the main source of the sediment was the Broken Hill-Olary basement high.

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Fig. 13. Correlation of Billy Creek Formation between Reaphook Hill and type section in Wirrealpa Basin. 2 m thick dolomite and overlying sequence of calcareous green shales in Section BC-B are correlated with grey marine limestone (Unit 11) at Reaphook Hill. Both units are fossiliferous, containing trilobite *Balcoracania* sp. Although sequences are tuffaceous, correlation of individual tuff beds between areas is not generally possible, and certainly not reliable.

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NEW ROTIFERA FROM AUSTRALIA

BY W. KOSTE & R. J. SHIEL

Summary

One hundred taxa of Rotifera, including six species: Lepadella chengalathi, L. williamsi, Lindia deridderi Koste, 1979, Testudinella walkeri, Filinia australiensis Koste, 1980 and F. hofmanni Koste, 1980 and five new subspecies are recorded from Australia for the first time. Eight new taxa in the genera Brachionus, Keratella, Lepadella, Lecane, Dicranophorus and Testudinella are redescribed and figured. Other species names, with ecological and locality information, are listed systematically.

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One hundred taxa of Rotifera, including six species: *Lepadella chengalathi*, *L. williamsi*, *Lindia deridderi* Koste, 1979, *Testudinella walkeri*, *Filinia australiensis* Koste, 1980 and *F. hofmanni* Koste, 1980 and five new subspecies are recorded from Australia for the first time. Eight new taxa in the genera *Brachionus*, *Keratella*, *Lepadella*, *Lecane*, *Dicranophorus* and *Testudinella* are described and figured. Other species names, with ecological and locality information, are listed systematically.

Introduction

Rotifera are found in virtually all inland waters. They are usually the numerically dominant component of the zooplankton of lakes, rivers, billabongs and swamps, providing an important link in aquatic food chains between the nannoplankton (i.e. less than 60 μm, including bacteria and micro-algae) and the carnivorous zooplankton.

Publication of the first checklist of the Australian Rotifera (Shiel & Koste 1979) and a review of the Australian species of *Brachionus* and *Keratella* (Koste 1979) has resulted in increased interest in the rotifer fauna. Workers locally and overseas have communicated papers and collections, enabling the faunal list to be expanded. The first material from the Northern Territory has been examined, and access has been provided to collections from Tasmania and Western Australia. Material from the other States has been collected during a survey of the zooplankton of the Murray-Darling system (Shiel 1978, 1979).

Consequently, while this paper adds to the known rotifer fauna of the continent, it must be considered as a preliminary to a more comprehensive treatment at a later date, in which illustrated keys will be provided for assistance in identification of the Australian Rotifera. At present, taxonomic references in which many of the cosmopolitan taxa are figured include Bartos (1959), Kutikova (1970) and Koste (1978), none of which is readily accessible to the English-speaking Australian limnologist.

One hundred taxa of Rotifera are recorded from Australia for the first time. In addition, three species (*Ascomorpha saltans*, *Pompholyx sulcata* and *Testudinella amphora*) are recorded by Sudzuki & Timms (1980) from farm dams in N.S.W. These species were recorded in the present study and are retained in the listing to provide ecological information. Sudzuki & Timms' record of *Filinia major* is considered synonymous with *F. terminalis* (see Koste 1978). A further three species described by Berzins (1961) were omitted from the original checklist, and are included here, bringing the recognised Rotifera taxa from Australia to 437. In some cases, taxa having minor differences from the type at the sub-specific or varietal level are the only representatives of the species recorded to date from the continent, and are therefore included in the record as distinct taxa following the principles of Mayr (1969).

Although it would be premature to give detailed ecological information on the collections, particularly since material from large areas of the continent has yet to be examined, we include information on the habitats from which the various taxa are recorded. The format adopted is as follows:

All records are listed systematically (after Koste 1978). Habitat type is indicated by:

L: lake or impoundment, with name of locality;

R: river or stream, with nearest town named;

B: billabong (standing waters on the floodplain), with nearest town or settlement named.

The season of collection is given as W: winter; Sp: spring; Su: summer and A: autumn.

Physico-chemical data is given in the sequence: temperature in °C (measured with a Yellow-Springs Instrument Company thermistor); pH (Metrohm portable pH meter);

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dissolved oxygen (YSI DO meter); turbidity (Hach turbidimeter, or where a metric measurement is given, by Secchi disc); conductivity (Radiometer CDM2 conductivity meter). In the example given below, the units of measurement for each parameter are given in parentheses:

Lecane stichaea Harring, 1913

Loc: R, Mannum, S.A., W; 11.0 (°C), 8.4 (pH), 10.8

(DO in ppm), 40 (turbidiity in Nephelometric Turbidity Units). 575 (μS cm^{-1}).

Several species came from collections other than by us. For these, physico-chemical data were not available to us.

No distinction is made between planktonic and littoral species. Seasonal variation occurs, particularly when billabong species are flushed into rivers to constitute the plankton in times of flood, as occurs in the Murray (Shiel 1979). Other species become established during algal blooms in lakes and rivers, using algal filaments or mats as substrates for attachment, and are thus seasonal or facultative plankters.

New taxa only are figured, with the exception of *Brachionus lyratus* Shephard (Fig. 1). This species was previously considered to be synonymous with *B. caudatus* (Ahlstrom 1943), however present samples indicate that the species is valid.

Abbreviations for the locations of type material are: ZMK, Zoological Museum, University of Kiel, D–2300, F.R.G.; SAM, South Australian Museum.

Systematics

ORDER BDELLOIDA

(See Shiel & Koste 1979, for known Australian bdelloid rotifers).

ORDER PLOIMIDAE Hudson & Gosse, 1886

Family Epiphanidae Bartos, 1959

Liliferotrocha subtilis (Rodewald), 1940

Loc: B, Thornton, Vic., A; 17.8, 7.1, 8.9, 28, –.

Rhinoglena frontalis (Ehrenberg), 1853

Loc: B, Yarrawonga, Vic., Sp; 14.5 ,8.2, 12.5, 18, 74

Family Brachionidae Kutikova, 1970

Brachionus quadridentatus f. *brevispinus* (Ehrenberg) 1832

Loc: L, Boort, Vic., Su; 23.5, 7.9, 6.0, 67, 750.

B. quadridentatus f. *cluniorbicularis* (Skorikow) 1894

Loc: B, Wodonga, Vic., Su.

B. variabilis (Hempel) 1896

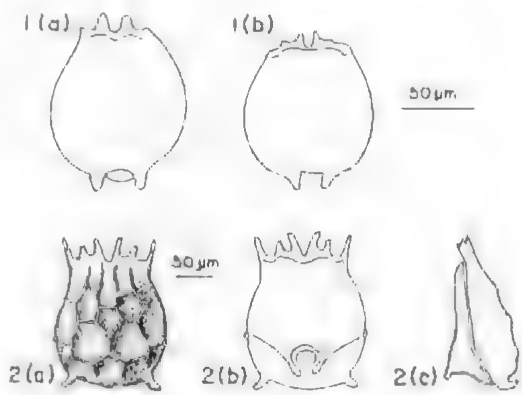
Loc: B, Wodonga, Vic., Su.

B. lyratus Shephard, 1911 (Fig.1)

Trophi preparation, Rot. No. 023, ZMK.

In Koste (1979) a *Brachionus* resembling that described by Shephard (1911) was figured. Harring (1913) suggested synonymy of the form with *B. angularis caudatus* Barrois & Daday 1894. Voigt (1937) considered the form insufficiently known, and Ahlstrom (1940) considered it synonymous with *B. angularis*. Examination of recent collections supports Shephard's comments on the peculiar morphological characteristics of this distinctive species. In particular, the presence of submedian spines, absent in *B. angularis*, and the "two knobbed projections (posteromedian spines) which curve outward in a manner suggesting the form of a lyre". Such foot-opening spines are not described for *B. angularis* or *B. caudatus*. On the basis of these taxonomic characteristics the independence of *B. lyratus* in the Formenkreis *angularis* is recognized. This now comprises the species groups *angularis*, *charini*, *dichotomus*, *dolabratus*, *forficula* and *lyratus* (see Koste 1978).

Measurements: Lorica length 120–145 μm, lorica width 90–96 μm, foot-opening width 20–24 μm, head-opening width 60–64 μm, subitaneous egg 65/45 μm.



Figs 1–2. 1—*Brachionus lyratus* Shephard, 1911. a,b. Lorica, ventral. Fig. 2—*B. bidentata* f. *testudinarius* (Jakubski) 1912. a. Lorica, dorsal. b. Lorica, ventral. c. Lorica lateral. Lorica length 220 μm. (cf. Fig. 4a, b).

Loc: B. Thornton, Vic., A; 17.8, 7.1, 8.9, 28.

B. dimidiatus (Bryce) 1931

Loc: B. Wodonga, Vic., A.

B. urceolaris sessilis (Varga) 1951

Loc: B. Jahiluka, N.T., W: 25.0, 6.15, 3.7, –, 48.

B. dichotomus reductus Koste & Shiel, 1979

Loc: B. Eskdale, Vic., Su; 29.2, 7.5, 8.0, 6, 85.

B. bidentata Anderson, 1889 (Figs 2–4)

B. bidentata minor n.ssp.

(FIG. 3a–h)

Material: 16 contracted females, sample No. 295, in formalin.

Holotype: loricate female, sample No. 295, coll. 28.xii.77, R. J. Shiel, Rot. No. 025, ZMK.

Paratypes: SAM, V,2092, Koste collection, Quakenbruck, F.R.G.

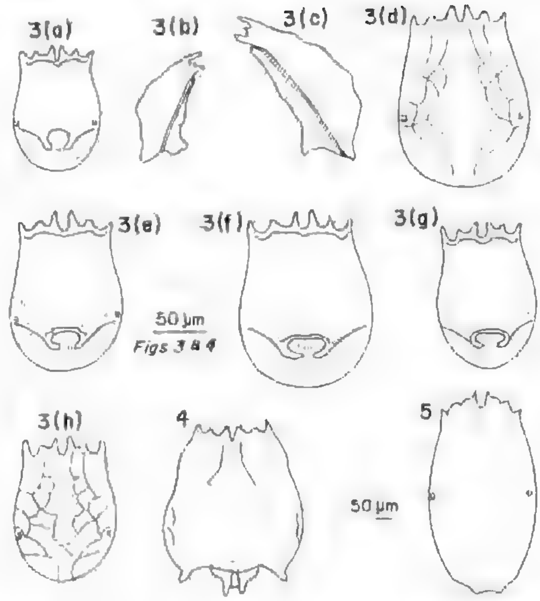
Iconotype: Fig. nostra 3a,b.

Type locality: River Murray, Mannum, S.A. (34°50'S/139°18'E).

Description: Small barrel-shaped lorica with six dorsal anterior spines. Short, unforked marginal spines (cf. Fig. 2c). Basal plate present. Semicircular dorsal lorica border. Anterior border of ventral plate slightly indented medially. Highly placed circular foot-opening. Posteromedian spines terminally button-shaped. Posterolateral spines absent. In larger specimens slight facettation dorsally (Fig. 3d, h). Lateral antennae marginally placed

Measurements: Lorica length 120–156 μm, lorica height 52-80 μm, greatest lorica width 84–108 μm, range of marginal spines 72–104 μm.

Discussion: The lorica shows comparative similarity to that of *B. bidentata* f. *inermis* (Rousselet) 1906. The latter however has long marginal spines, absent in *minor*. Moreover, this morph is an intermediate to *B. bidentata* f. *testudinarius* (Jakubski) 1912 (Fig. 2a–c), which has a short curved posterior spine. In the new subspecies the posterior border of the lorica is specifically semicircular. Comparison with *B. bidentata* f. *jirovci* (Bartos), 1947. Syn: *B. furculatus* var. *jirovci* Bartos, 1947 (Hauer 1963; Kutikova 1970) shows that this infrasubspecies taxon, in contrast to *B. bidentata minor*, has forked marginal spines, and also occasionally posterolateral spines.



Figs 3–5. 3—*Brachionus bidentata minor* n.ssp. a. Lorica, dorsal. b,c. Lorica, ventral. d. Another lorica, dorsal. e–g. Different loricas, ventral. f. Lorica with dorsal structure (all from the same population). Fig. 4—*B. bidentata* f. ?*testudinarius*. Lorica, dorsal. Length 170μm, width 140μm. Fig. 5—*B. plicatilis colongulaciensis* n.ssp. Lorica, dorsal. Lorica length 400 μm.

Considering the great variability of the species *B. bidentata* an exact taxonomic classification of the different morphs is difficult. For example, with regard to length of lorica spine development, Pourriot (1974) showed experimentally that this depended on the presence of the predator *Asplanchna brightwelli*.

The new subspecies is considered here as a "dwarf-form" *sensu* Green's (1977) study, where food-storage, salinity of biotope, etc., caused a reduction of lorica-size in crater lake rotifers.

Therefore the classification of *B. bidentata minor* as a subspecies i.e. a genetically distinct form, is provisionally documented here, noting however that only a single collection is involved.

Loc: R. Mannum, S.A., Su; 17.0, 8.2, 9.7, 86, 1,020.

Brachionus bidentata f. ? *testudinarius*

(FIG. 4)

In one sample from Lake Nillahcootie, Vic. (36°53'S/146°01'E) on 27.ii.78 an individual animal resembling the f. *testudinarius* was collected. Forked marginal spines are absent,

however, and the dorsal lorica is unstructured. The lorica has a resemblance to *Brachionus quadridentatus* var. *ancylognathus* (Schmarda 1859), but the elongated marginal spines, distinct lorica basal plate and the tube-like foot orifice indicate that this is a morph of *B. bidentata*.

Measurements: Lorica length 164 μm, greatest lorica width 140 μm, marginal spine length 68 μm, posterior spine length 100 μm.

Loc: L, Nillahcootie, Vic., Su; 26.0, 7.9, 11.3, 24, 55.

Brachionus plicatilis colongulaciensis n.ssp.
(FIG. 5)

Type material: 122 females of different ages, in formalin, sample number 647, collected by W. D. Williams, Lake Colongulac, Vic. (May 1979).

Holotype: Loricate female, coll. Williams 23.v.79, Rot.No.024, ZMK.

Paratype: SAM, V.2093; Koste collection, Quakenbrück, F.R.G.

Type locality: Lake Colongulac (salinity 10.4‰), W. Victoria (38°10′S/143°10′E).

Description: Greatly elongated transparent lorica. Surface unstructured. Anterior spines much reduced. Anterior border of ventral lorica with four short, flat, tongue-like projections. Posterior lorica margin tapered and rounded. Foot-opening terminal, lowered ventrally. Dorsal lateral antennae approximately level with mid-lorica. Ratio lorica length: width approximately 2:1.

Measurements: Lorica length (adult ♀) 400–440 μm, lorica width 210–240 μm, foot-opening width 40 μm, anterolateral spine development –75 μm, subitaneous egg 132–150 × 90–110 μm.

Discussion: In the population examined, all adult females had an extraordinary large lorica, corresponding in appearance to that of *B. plicatilis* f. *decemcornis* Fadeev, 1925. The latter has a different foot-opening (see Koste 1978) and is smaller. Hauer (1925) describes an elongated form from Bad Oldesloe with a cross-sectioned lorica length of only 260 μm. A lorica of approximately corresponding outlines was figured by Ahlstrom (1940) with a length of 275 μm and a greatest width of 210 μm. Neither of these is in accord with the Australian find. The greatest lorica length known to date is 315 μm.

It is apparent that the new ssp. population has arisen in Lake Colongulac in response to specific ecological pecularities of the habitat.

For the anatomy of this *Brachionus,* see Koste (1980a). For distribution of the species group see De Ridder (1960).

Loc: L, Colongulac, Vic., A; 12.7, 8.2, –, 42, 10.4 gm l^{-1}

Keratella procurva (Thorpe) 1891
(FIG. 6a–k)

This pantropical species, known previously only in its typical form (see Ahlstrom 1943, Berzins 1955 and Koste 1978), shows considerable variability in posterior spine development and overall lorica size. Paggi (1973) figures and reports on a series of different lorica forms (Fig. 6h) from the Parana River, Argentina.

In the many Australian samples examined, this species occurred also with variable lorica forms. The most abundant forms are figured (6a,f,g,i). A previously unknown form of the species group (Fig. 6b–e,j,k), notable in respect to its smallness and form of posterior spines, is documented below.

Keratella procurva robusta n.ssp.
(FIG. 6k)

Holotype: Female, coll. R. J. Shiel, Keepit Dam, N.S.W., 24.v.78, Rot. No. 026, ZMK.

Description: Short, squat, relatively wide and opaque lorica, ornamented with large pustules. Facetted as in f. typ., although with minor differences in populations from widely separated localities. All lorica spines, particularly short posterior spines, with wide bases (cf. Figs. 6b,j with 6d,h,i). Latter curved backwards in lateral view. Forms without caudal spines or with only a single posterolateral spine rudiment as in *K. tropica* (Apstein 1907) not recorded for *K. procurva.* Comparative morphological characteristics and measurements of known forms of *K. procurva* are as follows. In common forms (Figs 11a,f) the lorica surface is smooth or weakly granulated. Total lorica length from 155–220 μm; lorica width 67–80 μm; anterior spines 19–20, 17–22 and 30–40 μm and posterior spines 22–24 μm (left) and 27–64 μm (right). *K. procurva robusta* has a strongly studded lorica surface, total length 148–150 μm; lorica width 82–90 μm; anterior spines 15–17, 10–15 and 22–23 μm; posterior spines 14–15 μm (left) and 20–23 μm (right).

Loc: L,B,R, Darling catchment, Su; 10.5–25.0, 7.4–8.7, 6.4–10.8, 270–1000, 15–1000, 15–115.

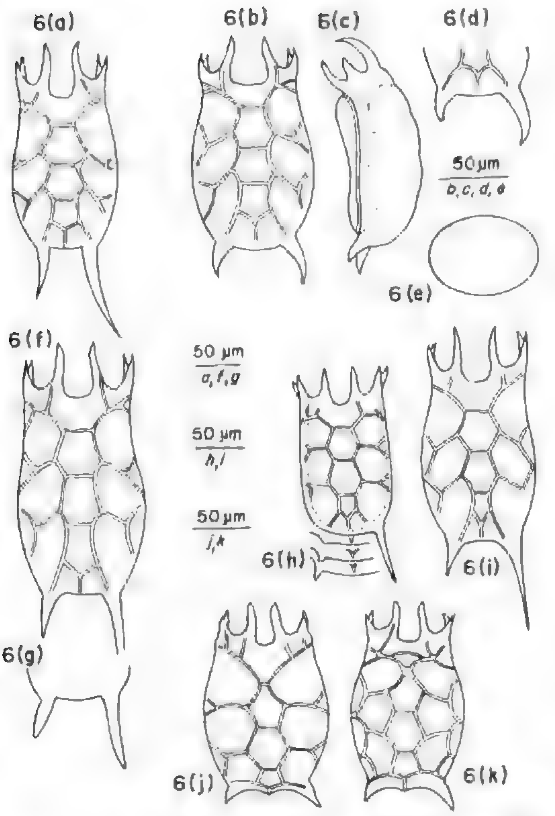


Fig. 6a. *Keratella procurva* (Thorpe) 1891. Lorica, dorsal. Morph with dorsolaterally curving posterior spines. S. Australia. Lorica length 220 µm. b. *K. procurva robusta* n.ssp. Lorica, dorsal, length 150µm. c. Lorica, lateral. d. Another specimen. e. Subitaneous egg of *K. procurva robusta*. f–g. K. *procurva* type, common form from Australian waters. h. *K. procurva*, variations from Argentinian waters, S. America (after Paggi, 1973). i. *K. procurva* from Australian warm waters, N.T. Lorica length to 230 µm. j,k. Two forms of *K. procurva robusta* from Darling River waters.

Notholca squamula (Muller), 1786
Loc: R, Donald, Vic., A; 11.0, 8.0, 11.2, –, –.

Anuraeopsis navicula Rousselet, 1910
Loc: B, Yea, Vic., A; 10.5, 7.2, 10.1, 33, –.

A. coelata De Beauchamp, 1932
Loc: B, Jabiluka, N.T., W; 25.0, 6.2, 3.0, –, 48.

Family Euchlanidae Bartos, 1959

Euchlanis dilatata f. *unisetata* (Leydig), 1854
Loc: B, Seymour, Vic., W; 10.0, 7.2, 11.6, 62, 330.

E. proxima Myers, 1930
Loc: R, Wyangala, N.S.W., Su; 15.5, 7.3, 10.2, –, –.

Dipleuchlanis propatula (Gosse), 1886
Loc: B, Jabiluka, N.T., W; 25.5, 6.2, 2.9, –, 62.

Family Mytilinidae Bartos, 1959

Mytilia macracantha (Gosse), 1886
Loc: B, Jabiluka, N.T., W; 24.5, 6.3, 5.8, –, 59.

M. bisulcata Lucks, 1912
Loc: B, Jabiluka, N.T., W; 25.5, 6.2, 2.9, –, 62.

M. crassipes (Lucks), 1912
Loc: B, Jabiluka, N.T., W; 25.0, 6.2, 3.0, –, 48.

Family Trichotridae Bartos, 1959

Wolga spinifera (Western), 1894
Loc: R, Wentworth, N.S.W., A; 10.0, 8.0, 10.2, 12, 675.

Family Colurellidae Bartos, 1959

Colurella adriatica Ehrenberg, 1831
Loc: L, Boort, Vic., Su; 27.5, 7.9, 6.0, 67, 750, R, Benalla, Vic., A; 8.5, 7.0, 11.2, 21, 575.

Squatinella mutica (Ehrenberg), 1832
Loc: B, Yea, Vic., A; 19.9, 7.2, 8.5, 0.8 m, 85.

Lepadella ehrenbergi (Perty), 1850
Loc: B, Jabiluka, N.T., W; 24.0, 6.25, 5.1, –, 42.

L. elliptica Wulfert, 1939
Loc: B, Jabiluka, N.T., W; 25.5, 6.2, 2.9, –, 62.

L. rhomboides rhomboides (Gosse), 1886
Loc: B, Jabiluka, N.T., W; 24.5, 6.3, 5.8, –, 59.

L. rhomboides f. *carinata* (Donner), 1934
Loc: R, Benalla, Vic., Su; 27.0, 7.6, 7.0, 52, –.

L. dactyliseta (Stenroos), 1898
Loc: R, Benalla, Vic., Su; 27.0, 7.6, 7.0, 52, –.

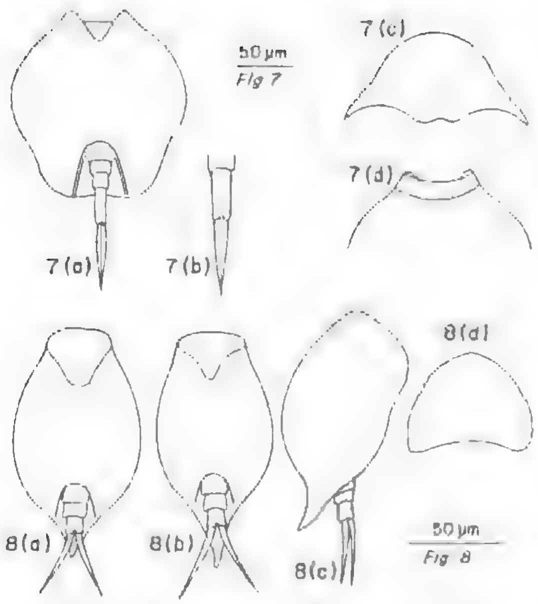
L. benjamini Harring, 1916
Loc: L, Boort, Vic., Su; 20.0, 7.4, 8.8, –, –. B, Jabiluka, N.T., W; 24.0, 6.25, 5.1, –, 42.

L. heterodactyla Fadeew, 1925
Loc: L, Boort, Vic., Su; 20.0, 7.4, 8.8, –, –.

L. apsicora Myers, 1934
Loc: L, Boort, Vic., Su; 23.5, 7.9, 6.0, 67, 750.

L. neboissi Berzins, 1960
Loc: R, Kinglake West, Vic., Sp.

L. ptilota Berzins, 1960
Loc: R, Clunes, Vic., W.



Figs 7–8. 7—*Lepadella chengalathi* n.sp. a. Lorica, ventral. b. Distal foot-segment with toes enlarged. c. Lorica cross-section. d. Neck aperture, dorsal. e. Ventral aspect. Fig. 8—*L. williamsi* n.sp. a,b. Ventral aspects of two loricas. c. Lateral view. d. Lorica cross-section.

L. angusta Berzins, 1960

Loc: R. Morang, Vic., Su.

L. monodactyla Berzins, 1960

Loc: B. Jabiluka, N.T., W: 25.5, 6.15, 2.9, –, 62.

L. heterostyla (Murray), 1913

Loc: L. Boort, Vic., Su; 23.5, 7.9, 6.0, 67, 750.

L. latusinus (Hilgendorf), 1899

Loc: R Benalla, Vic., Su: 27.0, 7.6, 7.0, –, –.

Lepadella chengalathi sp.nov.

(FIG. 7a–e)

Type material: 3 loricate ♀♀, sample number 307.
Holotype: Female, sample number 307, coll. R. J. Shiel, Rot No. 021, ZMK.

Type locality: Lake Boort, endorheic (internal) drainage, near Loddon River, Victoria (36° 08′S/143°45′E).

Description: Rhomboidal lorica (Fig. 7a) with rounded corners, widest in first third. Head opening small, not drawn down ventrally. Foot-opening semicircular at widest point of caudal boundary of dorsal lorica, which is weakly arched towards interior. Three flexible foot-articulations, distalmost slender and elongated. Toes symmetrical, long, needle-like and straight (Fig. 7b). Lorica cross-section shows highly vaulted dorsal lorica with slender downward-drawn lateral wings. Ventral plate with delicate double convex keel (Fig. 7c).

Measurements: Total length 135–140 µm, lorica height 48 µm, lorica length 96 µm, lorica width 92 µm, head-opening width 28 µm, foot-opening 28 × 28 µm, distal foot-articulation 19–20 µm, toe-length 33–36 µm.

Discussion: The new species has similarities with *Lepadella benjamini* Haring, 1916. In this species, however, the head-opening is cap-like, more or less ventrally drawn down, and the distal foot-articulation is not elongated (12–13 µm). Cf. also an Amazonian form described by Koste (1972, 1978) *L. benjamini* f. *brasiliensis* with rounded side rims. The genus is reviewed by Chengalath (1976).

Etymology: Named after Rama Chengalath, National Museum of Canada, Ottawa, in appreciation of years of scientific cooperation and friendship with W.K.

Loc: L. Boort, Vic., Su; 23.5, 7.9, 6.0, 67, 420.

Lepadella williamsi n.sp.

(FIG. 8a–d)

Holotype: Loricate female, sample number 657, coll. R. J. Shiel, 13.vi.79, Rot. No. 19, ZMK.

Paratype: SAM V.2904; number 657 Koste collection, Quakenbrück, D–4570 F.R.G.

Type locality: Ja-Ja Billabong, Jabiluka, N.T. (12°40′S/133°00′E).

Description: Smoothly oval, highly-vaulted lorica (Fig. 8d) with ventrally-directed head-opening. Dorsal lorica tapers caudally to a variable-length dorsal and laterally curved point (Figs 8a,b). Foot-opening narrow and ends at base of dorsal lorica projection. Only three flexible, approximately equal length foot segments visible. Last segment with long, dorso-laterally curved sharp toes.

Measurements: Total lorica length 112–116 µm, lorica height –56 µm, lorica width 60–64 µm, toe length 36–40 µm, foot-opening 17–20 × 19–20 µm, head-opening 33–36 × 28–30 µm, distal foot-segment length 10 µm, caudal lorica projections 19–28 µm.

Discussion: The new species resembles the species group *L. acuminata*, which also occurs in Australia (Figs 9, 10), and which is characterised by a more or less elongated and occasionally split lorica point. However the margin of the foot-opening of this projection is closed (Fig. 9b, 10b). The lateral antennae, which are

dorsal to the basis of the caudal projection, in contrast to *L. williamsi* are very narrowly placed. In *L. acuminata* and its various modifications (Koste 1978) the dorsal margin of the head-opening is more or less concavely cut out.

The new species was previously seen in a sample from a tank near Kuala Lumpur, Malaysia collected by C. H. Fernando, University of Waterloo, Ontario, Canada.

Etymology: Named after W. D. Williams, Dept of Zoology, University of Adelaide for assistance in collecting rotifer material and support toward this work.

Loc: B. Jabiluka, N.T., W; 25.5, 6.15, 2.9, 5, 62.

Heteroleapdella ehrenbergi (Perty), 1950
Loc: B. Eskdale, Vic., Su; 29.2, 7.5, 8.0, 6, 85.

Family Lecanidae

Lecane hornemanni (Ehrenberg), 1834
Loc: B. Yea, Vic., A; 19.9, 7.2, 8.5, .8 m, 85. B. Jabiluka N.T., W; 24.5, 6.3, 5.8, –, 59.

L. ludwigi (Eckstein), 1893
Loc: B. Jabiluka, N.T., W; 25.5, 6.15, 2.9, 5, 62.

L. aculeata (Jakubski), 1912
Loc: B. Jabiluka, N.T., W; 24.0, 6.25, 5.1, –, 42.

L. stichaea Harring 1913
Loc: R. Mannum, S.A., W; 11.0, 8.4, 10.8, 40, 575.

L. curvicornis (Murray), 1813
Loc: B. Jabiluka, N.T., W; 25.0, 6.2, 3.0, –, 48.

L. furcata (Murray), 1913
Loc: B. Jabiluka, N.T., W; 24.5, 6.3, 5.8, –, 59.

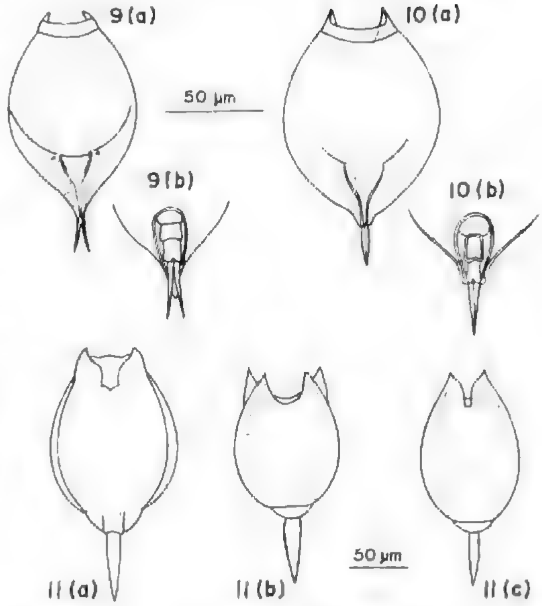
L. grandis (Murray), 1913
Loc: B. Jabiluka, N.T., W; 25.0, 6.2, 3.0, –, 48.

L. doryssa Harring, 1914
Loc: B. Jabiluka, N.T., W; 24.5, 6.3, 5.8, –, 59.

L. crepida Harring, 1914
Loc: B. Jabiluka, N.T., W; 25.0, 6.2, 3.0, –, 48.

L. tenuiseta Harring, 1914
Loc: B. Jabiluka, N.T., W; 25.0, 5.85, 2.2, –, 29.

L. lunaris crenata (Harring), 1923
Loc: L. Yarrawonga, Vic., Su; 24.2, 7.7, 8.6, –, 60.



Figs 9–11. 9—*Lepadella acuminata* (Ehrenberg), 1834 from N.T. a. Lorica, dorsal. b. Foot-opening and toes, ventral. Fig. 10—*L. acuminata* form with abbreviated caudal lorica point from N.T., Australia. a. Dorsal. b. Foot-opening and toes, ventral. Fig. 11—*Lecane (Monostyla) hamata victoriensis* n.ssp. a. Ventral view, lorica contracted. b. *L. hamata hamata* Stokes 1896. c. *L. sinuata* Hauer, 1938.

L. unguitata (Fadeew), 1925
Loc: B. Jabiluka, N.T., W; 25.0, 6.2, 3.0, –, 48.

L. acronycha Harring & Myers, 1926
Loc: B. Jabiluka, N.T., W; 25.0, 6.2, 3.0, –, 48.

L. inopinata (Harring & Meyers), 1926
Loc: L. Wyangala, N.S.W., Su; 27.0, 7.4, 7.5, 0.5, 245.

L. pertica Harring & Myers, 1926
Loc: B. Jabiluka, N.T., W; 24.5, 6.3, 5.8, –, 59.

L. elsa Hauer, 1931
Loc: B. Alexandra Vic., Sp; 20.0, 7.2, 9.1, –, –.

L. nodosa Hauer, 1938
Loc: B. Jabiluka, N.T., W; 24.5, 6.3, 5.8, –, 59.

L. ruttneri Hauer, 1938
Loc: L. Boort, Vic., Su; 20.0, 7.4, 8.8.

L. hamata victoriensis n.ssp.
(FIG. 11a)

Type material: 2 loricate ♀♀, sample number 263. *Holotype*: loricate ♀, sample number 263, coll. R. J. Shiel (14.x.77) Rot. No. 029, ZMK.

Type locality: Billabong "Goulburn View", near Alexandra, Victoria (37°13′S/145°42′E) from *Juncus* bed, 30 cm depth.

Description: Both anterior points of dorsal lorica at head aperature are congruent with ventral lorica, therefore not visible. Whereas this aperature in type flat or deeply curved, in spp. it is a deep trapezoid notch, basally 8 μm wide, bordered by light, curved lines. Lorica outline widely oval. Ventral plate smaller than dorsal plate. Toe gradually tapering from point of insertion at second foot segment.

Discussion: Morphologically, this ssp. shows several characteristics in agreement with *L. (M.) sinuata* Hauer, 1938 (Fig. 11c). A similar rotifer also was described from India by Wulfert (1966) as *L. arcuata* (Bryce), however the notch between the anterior spines in this latter form are otherwise shaped, and significant differences are seen in the measurements.

Measurements (in μm) are given in the following sequence: overall length, dorsal plate, ventral plate anterior transverse width, toe length, form of neck opening for each form of *L. hamata*. f. typica 103–136, 61–88 × 52–66, 77–98 × 40–60, 18–30, 26–38 double semicircular. v. *sinuata* 108–110, 74–76 ×53–55, 80–82 × 41–46, 21, 28, curved. v. *arcuata* 100, 52 × 56, 70 × 40, 25, 28, semicircular. v. *thienemanni* 113–123, 64–70 × 62–64, 77–88 × 46–55, 26–35, 33–34, ventral flat-concave, dorsal straight. *victoriensis* 124, 84 × 64, 92 × 56, 24, 32. trapezoid. Fig. 11a shows morphological differences of the new spp. from that described by Stokes, 1896 (Fig. 11b). In contrast to *L. h. victoriensis, L. h.* var. *thienemanni* has a characteristic horizontal dorsal lorica margin, and the toe is distended in the middle.

Loc: B, Alexandra, Vic., Sp; 20.0, 7.2, 9.1, 2, 115.

Family Proalidae Bartos, 1959

Proales fallaciosa Wulfert, 1937

Loc: B, Jabiluka, N.T., W; 24.5, 6.3, 5.8, –, 59.

Family Lindiidae Dujardin, 1841

Lindia torulosa Dujardin 1841

Loc: B, Yea, Vic., W; 11.0, 7.2, 6.1, 17, 170.

L. deridderi Koste, 1979

Loc: B, Wodonga, Vic., W; 10.2, 7.2, 9.0, 4, 154.

Family Notommatidae Remane, 1933

Itura myersi Wulfert, 1935

Loc: B. Wodonga, Vic., Sp; 14.7, 7.1, 4.1, 5, 240.

Eothinia elongata (Ehrenberg), 1832

Loc: B, Wodonga, Vic., Sp; 14.7, 7.1, 4.1, 5, 240.

Monommata grandis Tessin, 1890

Loc: B Jabiluka N.T., W; 24.5, 6.3, 5.8. –, 59.

M. actices Myers, 1930

Loc: B, Jabiluka, N.T., W; 25.0, 6.15, 3.7, –, 48.

M. arndti Remane, 1933

Loc: B, Alexandra, Sp; 20.0, 7.2, 9.1, –, –.

Notommata glyphura Wulfert, 1935

Loc: B, Alexandra, Vic., A; 17.8, 7.2, 8.9, 8, –.

Cephalodella eva (Gosse), 1886

Loc: B. Eildon, Vic., A; 17.9, 7.2, 9.2, 0.5, 87.

C. mucronata Myers, 1924

Loc: R, Mungindi, N.S.W., A; 16.0, 8.1, 9.2, –, –.

C. panarista Myers, 1924

Loc: B, Jabiluka, N.T., W; 25.5, 6.2, 2.9, –, 62.

C. ventripes Dixon-Nuttall, 1901

Loc: B, Wodonga, Vic., Sp; 14.7, 7.1, 4.1, 5, 240.

Family Trichocercidae Remane, 1933

Trichocerca cavia (Gosse), 1889

Loc: B, Eildon, Vic., A; 18.0, 7.1, 11.0, 0.5, 70.

T. collaris (Rousselet), 1896

Loc: B, Jabiluka, N.T., W; 24.5, 6.3, 5.8. –, 59.

T. chattoni (De Beauchamp), 1907

Loc: L, Wyangala, N.S.W., Su; 27.0, 7.4, 7.5, 0.5, 245.

T. myersi (Hauer), 1931

Loc: B, Jabiluka, N.T., W; 24.0, 6.25, 5.1, –, 42.

T. flagellata Hauer, 1937

Loc: B. Jabiluka, N.T., W; 18.0, 6.1, 6.7, –, 63.

T. mus Hauer, 1938

Loc: L, Nagambie, Vic., Su; 15.0, 7.4, 8.9, 1.3m, –.

T. jenningsi Voigt. 1957

Loc: B, Jabiluka, N.T., A; 29.0, 6.5, 2.9, –, 28.

T. similis grandis (Hauer), 1965
Loc: B, Wodonga, Vic., Sp; 15.5, 7.0, 10.8, 16, 43.

T. agnatha Wulfert, 1939
Loc: R, Echuca, Vic., Su; 15.0, 7.6, 9.0, –, –.

Ascomorphella volvocicola (Plate), 1886
Loc: B, Thornton, Vic., A; 12.4, 7.1, 8.6, 2.5, 115.

Family Gastropodidae Remane, 1933

Ascomorpha saltans Bartsch, 1870
Loc: L, Burrinjuck, N.S.W., Su; 26.0, 7.6, 8.0, 1, 190.

Family Synchaetidae Remane, 1933

Synchaeta tavina tavina Hood, 1893
Loc: L, Kerang, Vic., W.

S. litoralis Rousselet, 1902
Loc: B, Wodonga, Vic., W; 10.2, 7.2, 9.0, 4, 154.

Family Dicranophoridae Remane, 1933

Dicranophorus uncinatus (Milne), 1886
Loc: B, Wodonga, Vic., A.

D. aquilus (Gosse), 1887
Loc: R, Mungindi, N.S.W., A; 16.0, 8.1, 9.2, –, –.

Dicranophorus claviger australiensis n.ssp.
(FIG. 12a,b)

Type material: 14 ♀♀, sample number 669.

Holotype: female, coll. 13.vi.79, R. J. Shiel, Rot. No. 027, ZMK.

Type locality: Ja Ja Billabong, Magela Creek floodplain, confluent of Alligator River near Jabiluka, N.T. (12°40'S/132°50'))

Description: Elongate spindle-shaped body. Integument rigid, longitudinal lines from neck to short horizontal line on dorsal part. Head part cylindrical with moderate concave outlines. Small prolongation of dorsal lorica over foot. Toes extremely long and slender, curve somewhat outward, end in acute pointed claws seen only in lateral view. Corona with two frontal eyes and paired knobbed palps. Trophi large. Rami terminate with small teeth as in the trophi of *D. caudatus* (Fig. 12c) but have broad lamellar alula, which are apically elongated, ending in pair of double short teeth. Unci each have only a tooth. Short fulcrum has broad triangular form. Manubria slightly curved, spatulate ended. Beneath unci contact point is lamellar triangular element. Preservation in formalin precludes discussion of internal organization.

Discussion: This species is related to *D. caudatus*, from Victoria, and *D. claviger*, from South America by virtue of its morphology. Comparative information on the related forms is given below. Affinity of this ssp. with *D. claviger* (Hauer) 1965 is suggested by the palp number and similar trophi structure, although *D. claviger* (= *Itura claviger* Hauer, 1965) has a different shaped fulcrum, shorter toes and a significantly shorter overall length.

Measurement (in μm) and comments are given in the sequence overall length, greatest width, palp number, palp length, toe length, trophi length, manubrium form, uncus, fulcrum, rami, manubrium, teeth on ramus point, supra-rami teeth, supra-rami teeth length, distribution: *D. caudatus* Ehrenberg, 180–310, 90, 1, 9–10, 69–77, 34–36, sticklike, 13, 6, 21, 25, –, absent, –, cosmopolitan; *D. caudatus braziliensis* Koste, 1972, –330, –, ?, ?, 84–88, 48, terminally crutch-like, 32, 8, 26, 32, 4, absent, –, Amazon, S. America; *D. claviger* (Hauer) 274, 100, 2, 16, 24–44, 41–46, terminally broad, 17, 11, 32, 24, 4–5, oralplate (?), –, Amazon, S. America; *D. claviger* n.ssp., –532, –120, 2, –21, 155–164, 50–53, terminally broad, 34, 13, 40, 39, 6, present, 18, N. Aust.

Loc: B, Jabiluka, N.T., W; 23.5, 5.8, 2.4, –, 30.

Aspelta psitta Harring & Myers, 1928
Loc: B, Wodonga, Vic., W; 10.2, 7.2, 9.0, 4, 154.

Encentrum gibbosum Wulfert, 1936
Loc: R, Wangaratta, Vic., A; 12.0, 7.7, 10.0, –, –.

ORDER GNESIOTROCHA De Beauchamp, 1965

Family Testudinellidae

Testudinella parva (Ternetz), 1892
Loc: B, Jabiluka, N.T., W; 25.0, 6.2, 3.0, –, 48.

T. emarginula (Stenroos), 1898
Loc: B, Yea, Vic., A; 12.0, 7.3, 9.8, –, –.
R, Benalla, Vic., Su; 27.0, 7.6, 7.0, –, –.

T. tridentata Smirnov, 1931
Loc: L, Yarrawonga, Su; 24.2, 7.7, 8.2, 22, 160.
B, Jabiluka, N.T., W; 24.5, 6.3, 5.8, –, 59.

T. amphora Hauer, 1938
Loc: B, Jabiluka, N.T., W; 24.5, 6.3, 5.8, –, 59.

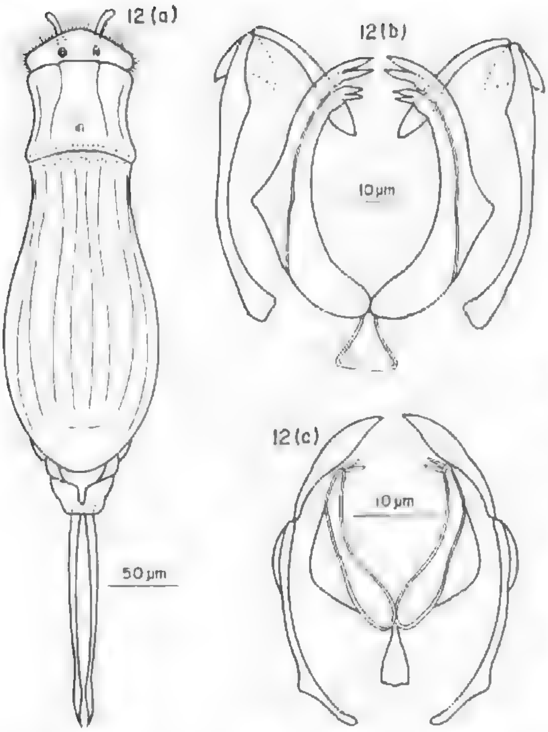


Fig. 12. *Dicranophorus claviger australiensis* n.ssp. a. Dorsal view, total length 532 µm. b. Trophi, dorsal view, length 53 µm. c. Comparative view of trophi of *D. caudatus* (Ehrenberg, 1834), length 35 µm.

Testudinella walkeri n.sp.

(FIG. 13a,b,c,d,e)

Type material: 6 ♀♀, preserved in formalin, sample number 659.

Holotype: Loricate female, sample number 659, coll. 13.vi.79, R. J. Shiel. Rot. No. 020, ZMK.

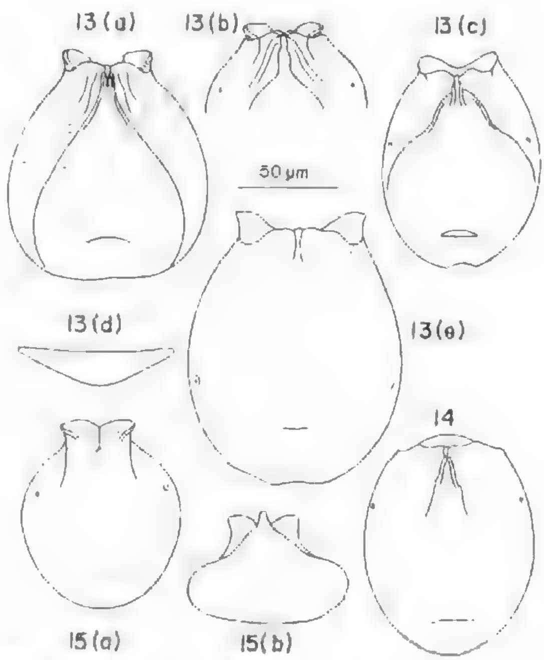
Type locality: Mine Valley billabong, Magela Creek floodplain, tributary of Alligator River near Jabiluka, N.T. (12°40′S/132°50′E).

Description: Juvenile lorica (Fig. 13b,e) widely oval, strongly circular outline in adults (Fig. 13a). Dorsal lorica slightly concave at widest point. Ventral lorica under neck-aperature with keel-like folding, two edges of which curve outwards to lower lorica rim. Foot-opening slit-like under middle of ventral lorica. Dorsal anterior rim of head-aperature with rounded, bulge, medially lightly notched (Fig. 13b). In poor preparations this can appear concave (Fig. 13c). Lorica end with shallow indentation. Lateral antennae located slightly above lorica midline. Lorica cross-section shallow, triangular (Fig. 13d).

Measurements: Lorica length overall 100–112 µm, greatest lorica width 75–98 µm, neck aperature width 40–44 µm, greatest lorica height in midline 20–25 µm, foot-opening 20 µm over the posterior lorica rim, foot-opening width 20–24 µm.

Discussion: The new species belongs on the Formenkreis *incisa* (see Koste 1978). A typical form from this group from the same sample is shown in Fig. 14. All are described with oval or egg-shaped lorica outlines, as are the adult individuals of the *brycei-amphora* group (Koste 1978). With the exception of *T. amphora* Hauer, 1937, neither of these groups has the ear-shaped lateral elevation of the dorsolateral rim of the neck aperture.

The new species is characterised by this projection on the upper rim of the wide lorica, by the presence of the two prominent ventral diverging lines which begin at the keel-like crease under the ventral margin of the neck aperture.



Figs 13–15. 13—*Testudinella walkeri* n.sp. a. Ventral. b. Anterior lorica detail, contracted. c. Juvenile lorica, ventral. d. Lorica cross-section. e. Species from Malaysia, lorica, ventral. Single individual collected. Fig. 14—*T. incisa* var. *emarginula* (Stenroos), 1898. Lorica length 110 µm, lorica width 85 µm. Fig. 15—*T. amphora* Hauer, 1937 from N.T. a. Dorsal b. Ventral, oblique. Lorica length 96 µm, lorica width 78 µm.

A lorica of similar form but lacking the wide ventral keel was found in a sample from Malaysia (coll. C. H. Fernando, University of Waterloo, Canada).

Comparative measurements (in μm) are given in the sequence lorica length, lorica width, foot-opening, neck aperture, lorica cross-section: *T. walkeri* n.sp, 100–112, –98, slitlike, with lateral "ears" 40–44, shallow triangular; *T.* sp. from Malaysia, 136, 84, angular 16 × 10, with "ears" 64, shallow triangular; *T. amphora*, 90–95, 60–78, slitlike 18–20, with "ears", triangular; *T. brycei*, 85, 58, slitlike, medially tongued-shaped, triangular; *T. incisa* v. *emarginula*, 80–130, 65–82, slitlike, medially shallow, tongue-shaped shallow triangular.

Loc: B, Jabiluka, N.T., W: 24.5, 6.3, 5.8, –, 59.

Etymology: Named after Dr K. F. Walker, Department of Zoology, University of Adelaide, in appreciation of support during a Ph.D. program by RJS.

Family Flosculariidae Harring, 1913

Ptygura furcillata (Kellicott), 1889

Loc: L, Boort, Vic., Su: 23.5, 7.9, 6.0, 67, 750.

P. melicerta v. *mucicola* (Kellicott), 1889

Loc: B, Wodonga, Vic., Su.

P. tacita Edmondson, 1940

Loc: B, Yea, Vic., A: 19.9, 7.2, 8.5, .8 m, 85.

Family Hexarthridae Bartos, 1959

Hexarthra polyodonta (Hauer), 1957

Loc: B, Seymour, Vic., Sp: 18.0, 7.2, 9.4, –, 265.

Family Filiniidae Bartos, 1959

Filinia hofmanni Koste, 1980

Loc: R, Mannum, S.A., Su, A: –28.0, 7.7–8.4, –10.8, –135, –1080.

F. australiensis Koste, 1980

Loc: R, Mannum, S.A., Su; 17.0, 8.2, 9.7, 88, 1020.

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HETEROMORPH AMMONITES FROM THE ALBIAN OF SOUTH AUSTRALIA

BY K. J. MCNAMARA

Summary

The heteromorph ammonite Protanisoceras Spath is described from Australia for the first time. Five forms are recognised from the Albian Oodnadatta Formation in South Australia, including P. auriculum sp. nov. and P. gracile sp. nov. By comparison with species from the Albian of Europe, a Middle Albain age is suggested for part of the Oodnadatta Formation in which they occur. In addition Appurdiceras cordycepoides (Etheridge 1905) is redescribed and the relationships of the genus reassessed; a species of Hamites is described; and the Late Albian species Anisoceras sweeti sp. nov. described.

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by K. J. McNAMARA*

Summary

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The heteromorph ammonite *Protanisoceras* Spath is described from Australia for the first time. Five forms are recognised from the Albian Oodnadatta Formation in South Australia, including *P. auriculum* sp. nov. and *P. gracile* sp. nov. By comparison with species from the Albian of Europe, a Middle Albian age is suggested for part of the Oodnadatta Formation in which they occur. In addition *Appurdiceras cordycepoides* (Etheridge 1905) is redescribed and the relationships of the genus reassessed; a species of *Hamites* is described; and the Late Albian species *Anisoceras sweeti* sp. nov. described.

Introduction

Ammonites form a much less important part of the marine Cretaceous fauna of the Great Artesian Basin in South Australia than in Queensland; hence few species have been described. Albian ammonites were first described from S.A. by Etheridge (1905) who described "*Haploceras* sp., *Anisoceras* (?) sp., *Ancyloceras cordycepoides* and *Crioceras flindersi*" from the area of Dalhousie Springs. The "*Haploceras*" is probably *Falciferella* (see below). Whitehouse (1926) proposed *Appurdiceras* to accommodate *A. cordycepoides*, while "*C.*" *flindersi* belongs in *Myloceras* (Reyment 1964a; McNamara 1978). The only other Albian ammonites to have been described from S.A. are *Falciferella breadeni* and *F. reymenti* Brunnschweiler (1959) and a Late Albian fauna including species of *Myloceras* and *Labeceras* described by Reyment (1964 a,b). Ludbrook (1966) illustrated specimens which she referred to *Myloceras axonoides* (Etheridge) and *Labeceras papulatum* Whitehouse.

The present study is based primarily on collections from the Albian Oodnadatta Formation housed in the palaeontological collections of the S.A. Department of Mines & Energy (GSSA). The specimens were collected from calcareous nodules, which occur within a soft gypseous shale, mainly from Algebuckina 17 (Ludbrook 1966), 32 km SSE of Oodnadatta at lat. 27°49½'S, long. 135°34½'E. Additional specimens are from Toodla 8, which is 3 km SW of Mt Arthur at lat. 27°31'S and long. 135°41'E (Fig. 1).

Specimens identified from these localities (OODNADATTA 1:250 000 geological map sheet) are:

Protanisoceras auriculum sp. nov., *P. gracile* sp. nov., *P.* aff. *gracile* sp. nov., *Hamites* cf. *attenuatus* J. Sowerby 1814, *Falciferella* sp. (Ludbrook 1966, p. 44).

The second collection on which this work is based was obtained by G. Sweet from the Maree Subgroup and presented to the National Museum of Victoria (NMV) in 1914. The specimens are recorded as coming from "Primrose Springs, Peake Station". Ludbrook (1966) considered that this locality may be near Primrose Hill at 28°10'S, 136°25'E. From an early description, she now considers that Primrose Hill and Springs is a mound spring with seepage at the base and that the various

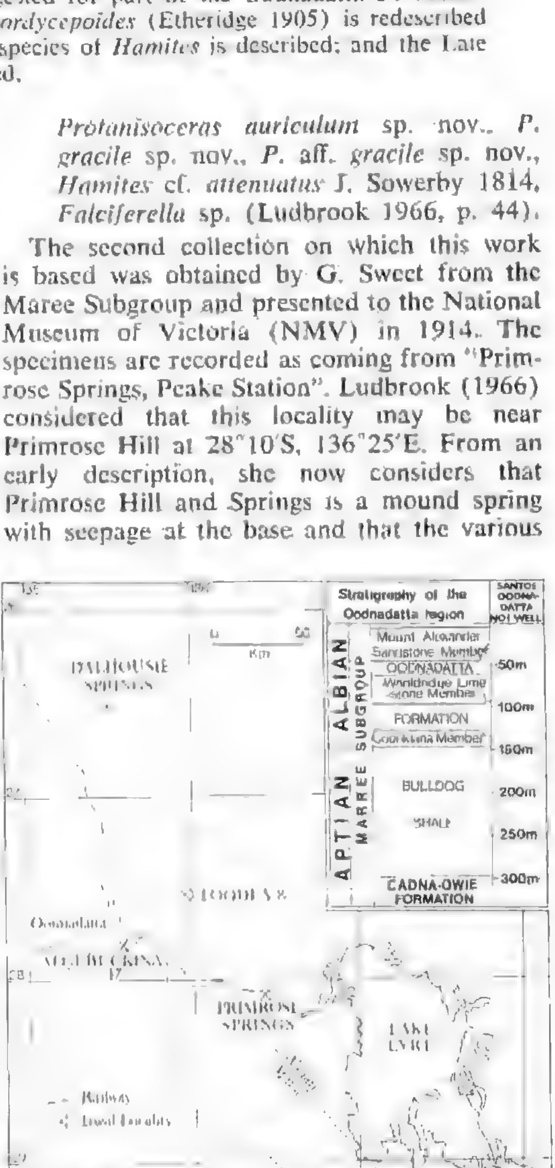

Fig. 1. Map showing fossil localities mentioned in text. Aptian/Albian boundary after Ludbrook (1966, Map 2). Stratigraphic information after Freytag (1966, Fig. 1).

* Western Australian Museum, Francis Street, Perth, W.A. 6000.

specimens collected from 'Primrose Springs' are from the general area along The Neales in the NE of the WARRINA 1:250 000 map sheet where both Aptian and Albian strata occur (Ludbrook 1966, Map 6; Thomson 1980). Specimens identified from this locality are:

> *Anisoceras sweeti* sp. nov., *Protanisoceras* sp. A, *P.* sp. B, *Hamites* cf. *attenuatus* J. Sowerby 1814, *Sanmartinoceras (Sinzovia) fontinale* (Hudleston 1890).

The age of the rocks at this locality is discussed below.

Finally, *Appurdiceras cordycepoides* (Etheridge 1905) is redescribed and reinterpreted on the basis of Etheridge's syntypes from the Oodnadatta Formation at Dalhousie Springs (Fig. 1), one of which is housed in the S.A. Museum (SAM), whilst the other has been located in the NMV. All material was collected from surface outcrop.

Systematic palaeontology

Family ANISOCERATIDAE Hyatt 1900

ANISOCERAS Pictet 1854

Type species: Hamites saussureanus Pictet *in* Pictet & Roux 1847.

Anisoceras sweeti sp. nov

FIGS 2, 6D

Etymology: Named after G. Sweet who obtained the specimens.

Holotype: NMV P52328, an incomplete phragmocone from "Primrose Springs, Peake Station".

Paratypes: NMV P52325, an incomplete phragmocone, and NMV P52326, an incomplete body chamber; both from same locality as holotype.

Age: Late Albian.

Diagnosis: Species of *Anisoceras* in which lateral and ventro-lateral ribs may cover up to three ribs; ribs broad and strongly prorsiradiate on phragmocone. Lateral lobe of suture three times width of umbilical lobe.

Description: Complete shell form unknown; description based on straight fragments. Whorl height slightly greater than whorl width. Phragmocone known from whorl height of 20–24 mm. Ornament consists of coarse, prosiradiate ribs which arise from lateral tubercles in twos or threes, and form loop with circular to elongate ventrolateral tubercles. The looped ribs form a swollen bundle between which usually lies one relatively depressed intercalated rib between the looped ribs. On dorsum are 12 ribs in a distance equal to the whorl height; ribs well developed on dorsum. Maximum known height of body chamber 27 mm. Ornament similar to that on phragmocone, though tubercles a little more widely spaced. Ventrolateral tubercles more elongate than on the phragmocone. Lateral lobe of suture bifid and large, covering more than half flank of phragmocone; three times width and about twice height of bifid umbilical lobe.

Discussion: A. sweeti is similar to *A. armatum* (J. Sowerby 1817) from the Late Albian *Stoliczkia dispar* Zone (Cooper & Kennedy 1979; Scholz 1979) in possessing prominent looped ribs with usually one intercalated rib. However, the ribs are only looped in pairs in *A. armatum*. Furthermore the ribs are more strongly prorsiradiate in *A. sweeti*. The two species can most easily be distinguished by the relative sizes of the lateral and umbilical lobes of the suture. In *A. armatum* they are of approximately equal size or the lateral is just slightly larger than the umbilical (Scholz 1979, Fig. 8). In *A. sweeti* the lateral lobe is very large, being three times the width of the umbilical lobe.

In *A. haasi* Cooper & Kennedy (1979) three, or four, ribs may be looped between the tubercles. However, the ribs are much finer than in *A. sweeti*.

APPURDICERAS Whitehouse 1926

Type species: Ancyloceras cordycepoides Etheridge 1905 p. 14, Pl. 1, figs 3–5, Pl. 2, fig. 4; by original designation of Whitehouse 1926, p. 229.

Emended diagnosis: Coiling ancyloceratid. Ribs strongly developed, widely spaced; bifurcate laterally and at umbilical tubercles on shaft. Ventrolateral spines regularly developed, bases covering one to three ribs and forming 'loop and button' ornament across venter. Ventrolateral spines on different ribs from umbilical tubercles. Umbilical lobe of suture bifid.

Remarks: Whitehouse (1926) proposed *Appurdiceras* to accommodate *Ancyloceras cordycepoides* Etheridge, distinguishing it from other Australian heteromorphs by its prominent ventrolateral spines. Whitehouse questioningly placed a single labeceratid specimen from Qld in this genus, calling it *A.*(?)

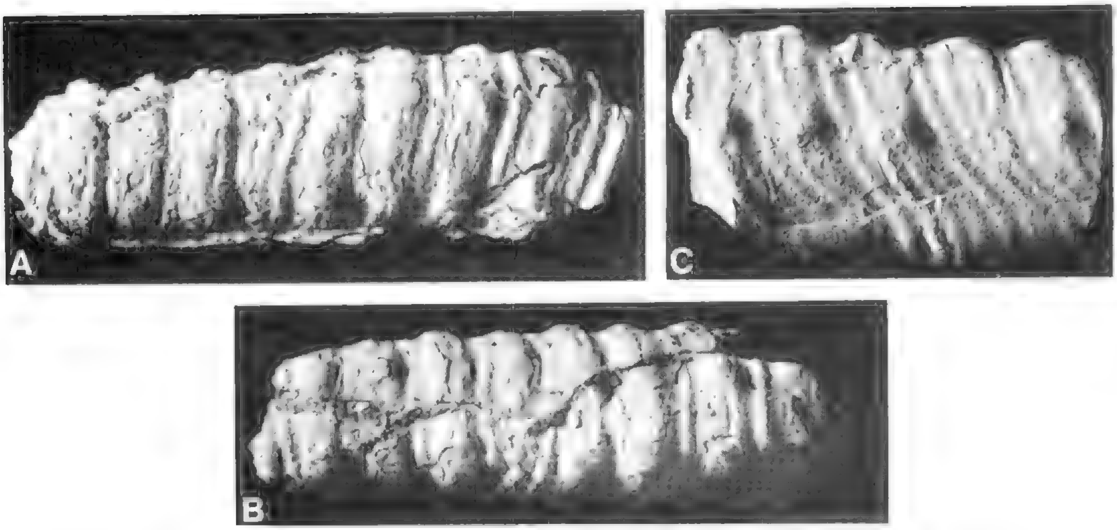

Fig. 2. *Anisoceras sweeti* sp. nov.; NMV P52328, holotype, A, lateral view, B, ventral view; C, NMV P52326, paratype, dorsolateral view; from "Primrose Springs", Peake Station; Oodnadatta Formation, Late Albian; all x 1.

etheridgei, with the result that *Appurdiceras* itself came to be thought of as a subgenus of *Labeceras* (Wright, *in* Arkell *et al.* 1957; Reyment 1964a; Klinger 1976) which bears ventrolateral tubercles. *A.*(?) *etheridgei* is quite unlike *A. cordycepoides*, being a true labeceratid which has ribs which do not bifurcate on the flanks of the shaft, as they do in *A. cordycepoides*, and which do not form the characteristic anisoceratid looped ribs across the venter. The umbilical lobe of labeceratids is trifid, whereas in *Appurdiceras* it is bifid.

Consequently, *Appurdiceras* is herein regarded as an anisoceratid and not a subgenus of *Labeceras*. Whitehouse (1926) included *Idiohamites spiniger* (J. Sowerby) from the English Late Albian in *Appurdiceras*. He also noted a similarity with *Hamites nodosus* J. Sowerby. This latter species was made the type of *Heteroclinus* by Casey (1961). However Klinger (1976) places this genus in synonymy with *Protanisoceras* (see below).

Unlike species of *Anisoceras* and *Protanisoceras*, which may bear both ventrolateral and lateral tubercles or spines, *Appurdiceras* possesses ventrolateral and umbilical tubercles. It can also be distinguished from these two genera by the umbilical bifurcation of the ribs on the shaft at tubercles which do not form by the coalescence of the ribs bearing the ventrolateral tubercles or spines, but by the coalescence of an intercalated rib with one which does bear a ventrolateral tubercle. The ribs may also occasionally bifurcate laterally. Species assigned to *Idiohamites* tend to have numerous, fine ribs between the tuberculate ribs (Spath 1939), though as Klinger (1976) has noted, *Idiohamites* grades into *Anisoceras*. *Anisoceras* and *Protanisoceras* differ from one another in the nature of the suture (see below). Whereas the umbilical lobe is trifid in *Protanisoceras* it is bifid in both *Appurdiceras* and *Anisoceras*.

Appurdiceras cordycepoides (Etheridge 1905)
FIG. 3

1905 *Ancycloceras cordycepoides* Etheridge, p. 14, Pl. 1, figs 3–5, Pl. 2, fig. 4.
1909 *Crioceras cordycepoides* (Etheridge); Etheridge, pp. 142, 156, 159, 160.
1926 *Appurdiceras cordycepoides* (Etheridge); Whitehouse, p. 230.
?1964 *Labeceras* (*Appurdiceras*) *cordycepoides* (Etheridge) Reyment, p. 25, ?Pl. 1, figs 6 & 7.
1969 *Appurdiceras cordycepoides* (Etheridge); Day, p. 156.
non
1966 *Labeceras* (*Appurdiceras*) *cordycepoides* (Etheridge); Ludbrook, p. 190.

Lectotype: Herein designated: NMV P30032, from Dalhousie Springs (DALHOUSIE 1:250 000 geological map sheet) figured by Etheridge (1905, Pl. 2, fig. 4).

Paralectotype: SAM P2990 from Dalhousie Springs; figured by Etheridge (1905, Pl. 1, figs 3–5).

Age: Late Albian.

Diagnosis: As for genus.

Description: Phragmocone initially ovoid in cross section and forms an open criocone for one whorl, then opens into a shaft. Whorl of lectotype has maximum radius of 22.8 mm. At a quarter whorl, whorl height is 4.5 mm; at commencement of shaft it is 8.5 mm. Early part of whorl damaged, and it is not known whether ribs are tuberculate. Ribs are known, however, to be rectiradiate and not bifurcant. Whorl section of shaft sub-circular. Ornament changes on shaft such that ribs become more widely spaced than on coiled, early part of phragmocone. Early ribs on shaft infrequently bifurcate on flanks. Bifurcations more common along shaft toward crozier. At these bifurcations tubercles are not developed. Bifurcations more commonly occur umbilically between a rib which bears a ventrolateral spine and an intercalated non-spinose rib. Ribs more strongly developed along shaft. Ventrolateral spines appear as rounded tubercles on internal mould. Across venter ribs which connect spines form a raised swollen band. A 'button and loop' ornament is formed across ventor by coalescence of three ribs at ventrolateral spines. Initially ribs on shaft rectiradiate, but become increasingly prorsiradiate adapertually. On dorsum ribs less well-developed, but do not disappear. Shaft almost twice length of maximum diameter of coiled phragmocone. Adaperturally the body chamber recurves to form crozier. Paralectotype reaches a maximum whorl height of 16 mm and a maximum whorl width of 14.5 mm. Suture incompletely known: umbilical lobe bifid and narrow; internal lobe trifid.

Discussion: Since the original description of the two type specimens the only specimens ascribed to this species are two from the Late Albian of Fossil Creek, Wooldridge Limestone Member, Oodnadatta Formation, locality 5/550/1, 42 km NW of Oodnadatta (Reyment 1964a) and specimens from Oodnadatta Formation, Algebuckina 17 (5/571/17), 13 km W of Mt Dutton (Ludbrook 1966). However, it is not possible for me to assign Reyment's fragmentary specimens to *A. cordycepoides* with any certainty as, although seemingly possessing an ovoid to subcircular whorl section and ventrolateral tubercles, there is no indication of bifurcation on the flanks of the shaft. In his description of these specimens Reyment does suggest the presence of occasional bifurcations. If these specimens are true members of *A. cordycepoides* their occurrence with species of *Myloceras* and *Labeceras* indicates that *Appurdiceras* may be a Late Albian form. Specimens referred to *A. cordycepoides* by Ludbrook are species of *Protanisoceras* (see below).

Etheridge's specimens were collected by H. Y. L. Brown from the region of Dalhousie Springs. Ludbrook (1966) has recorded both Albian and Aptian molluscs from this area. In addition to describing *A. cordycepoides* from the Dalhousie area, Etheridge described and illustrated other ammonites which have a Late Albian, rather than Aptian, affinity, including the Late Albian *Myloceras* and *Labeceras*.

The development of ventrolateral spines is seen in other anisoceratids, such as *Anisoceras* (Klinger 1976), *Idiohamites* (Spath 1939)

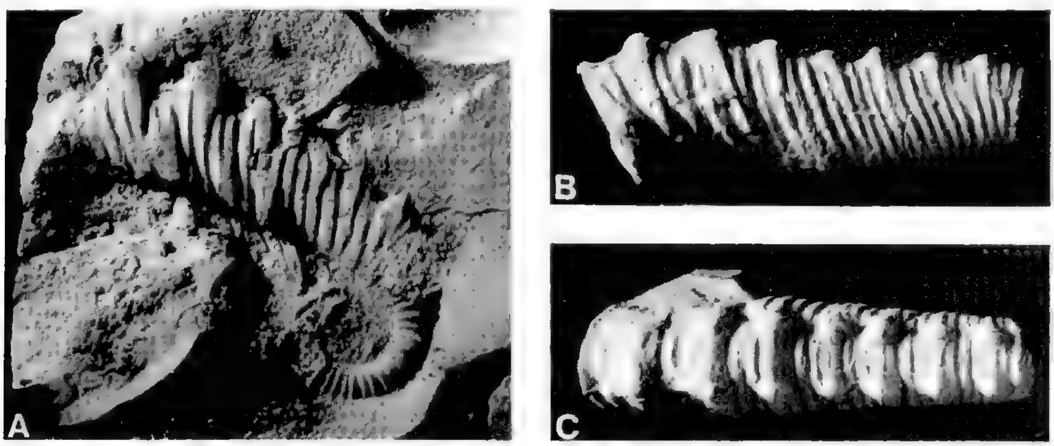

Fig. 3. *Appurdiceras cordycepoides* (Etheridge 1905); A, NMV P30032, lectotype, lateral view; SAM P2990, paralectotype, B, lateral view, C, ventral view; from Dalhousie Springs; Oodnadatta Formation, Late Albian; all x 1.

and *Protanisoceras* (Spath 1939). The two species from the English Late Albian, *Idiohamites spiniger* and *Protanisoceras nodosum*, with which Whitehouse (1926) compared *A. cordycepoides*, differ in lacking the bifurcation of the ribs on the flank of the shaft and having lateral tubercles developed on the same ribs as the ventrolateral spines.

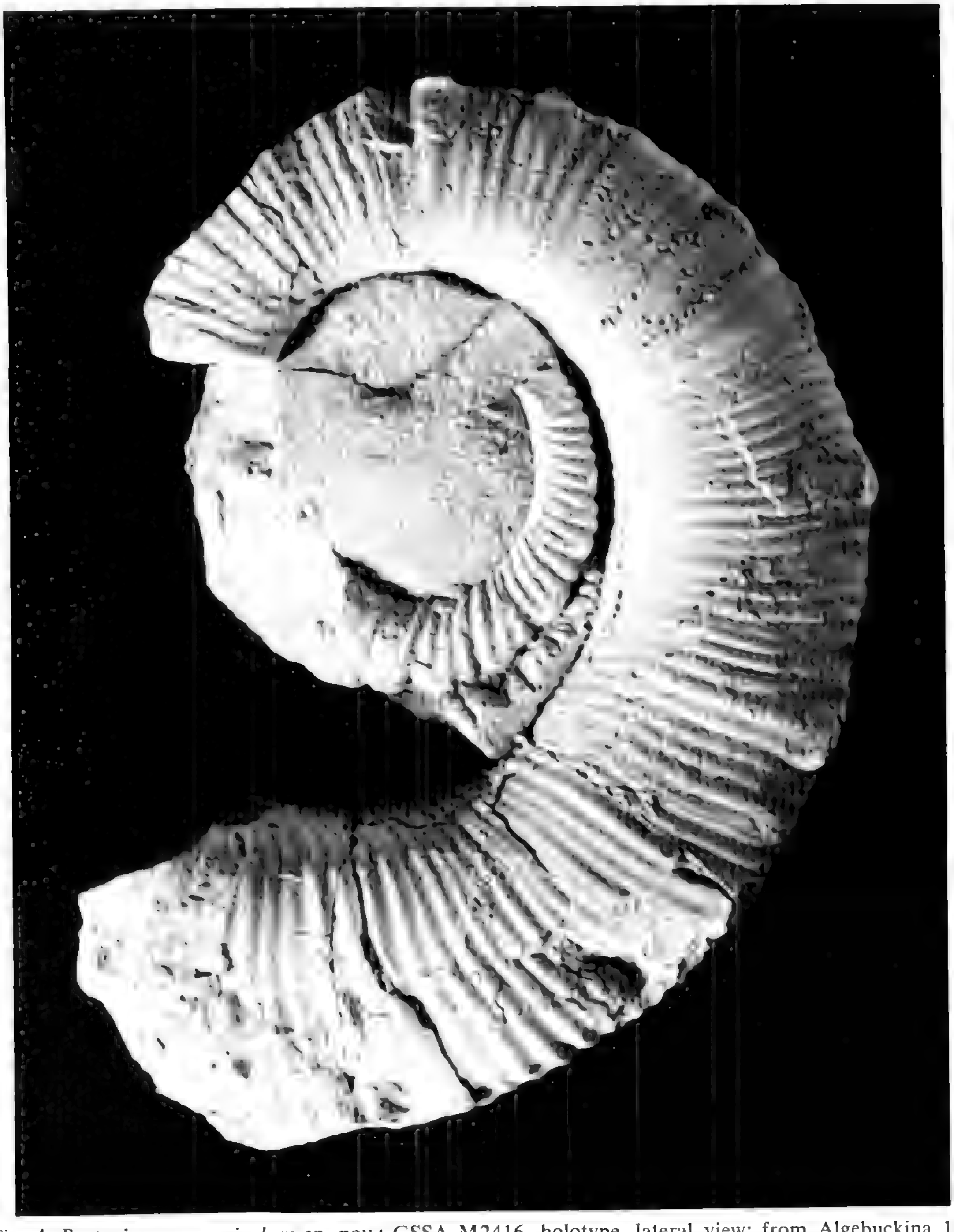

Fig. 4. *Protanisoceras auriculum* sp. nov.; GSSA M2416, holotype, lateral view; from Algebuckina 17, 32 km SE of Oodnadatta; Oodnadatta Formation, Middle Albian; x 1.

PROTANISOCERAS Spath 1923

Type species: Hamites raulinianus d'Orbigny 1842, p. 546, Pl. 134, figs 5–8; by original designation of Spath 1923, p. 75.

Remarks: Spath (1939) distinguished *Protanisoceras* from the morphologically similar *Anisoceras* by its smaller size, the more regularly planar coiling and simpler suture line which has a trifid umbilical lobe. Klinger (1976) has noted that this lobe is smaller than the lateral lobe in *Protanisoceras*, whereas he believed that it was of similar size to the lateral lobe in *Anisoceras*. The species of *Anisoceras* described here shows that even in some members of this genus the umbilical lobe may be much smaller than the lateral lobe. However, the trifid umbilical lobe of *Protanisoceras* and bifid umbilical lobe of *Anisoceras* are diagnostic.

Klinger (1976) has further noted that the coiling and ornamentation are variable within *Protanisoceras*. Both ventrolateral and lateral, or just ventrolateral tubercles or spines may be present; they may appear on all, or only some, ribs. The tubercles may be connected by one or more ribs. Furthermore, the ornamentation on the recurved crozier may vary considerably from the shaft.

Casey (1961) regarded *P. nodosum* as belonging within a separate genus, which he named *Heteroclinus*, on account of its 'button and loop' ornament. Klinger (1976) has preferred to regard *Heteroclinus* as a synonym of *Protanisoceras* as species such as *P. parcetuberculatum* Collignon show intermediate characters between *Protanisoceras* and *Heteroclinus* in possessing both single and looped ribs. This situation also occurs in one of the Australian species described below.

Protanisoceras auriculum sp. nov.
FIGS 4, 5, 6B, 9A–C

Etymology: Latin—*auriclum*—ear; pertaining to the shape of the shell.

1966 *Labeceras* (*Appurdiceras*) *cordycepoides* (Etheridge) (pars.); Ludbrook, p. 190.

1966 *Myloceras axonoides* (Etheridge); Ludbrook, pp. 44, 190 (pars.), Pl. 28, fig. 1.

Holotype: GSSA M2416, part of the phragmocone and body chamber (Figs 4, 5A); from Oodnadatta Formation, Algebuckina 17 (5/571/17) (Ludbrook 1966), 27°49½'S, 135°34½'E, 32 km SE of Oodnadatta, S.A., on North Creek, near its junction with Neales River (OODNADATTA 1:250 000 geological map sheet).

Paratypes: GSSA M2444, 3546, from the same locality as the holotype and M3547 from Toodla 8 (5/561/8), 3 km SW of Mt Arthur, 27°31'S, 135°41'E.

Other material: In addition to the type specimens, 12 further specimens are known: GSSA M2446, 2454, 3548–3556 from Algebuckina 17 and M3061, 3557 from Toodla 8.

Age: Middle Albian.

Diagnosis: Coiling aspinoceratid. Ventrolateral tubercles occur infrequently on single ribs on early phragmocone and late body chamber; occur more frequently on later phragmocone and early body chamber where may cover two or three ribs. Ribs broad and widely spaced on early phragmocone; becoming finer and more closely situated adaperturally.

Description: Phragmocone forms open coil throughout. Whorl section ovoid throughout, whorl height slightly greater than whorl width. At earliest known part of phragmocone (Fig. 5E) at whorl height of 4 mm, ornament consists of simple, non-tuberculate, slightly prorsiradiate ribs. At this stage there are four ribs in a distance equal to whorl height. At slightly greater whorl height every fifth or sixth rib is flattened across venter and small tubercles occur ventrolaterally. Up to a whorl height of 9 mm ribs become increasingly prorsiradiate; ribs more strongly inclined toward dorsum. Tubercles at this whorl height occur more frequently and become elongate, spreading across two ribs; up to two intercalated non-tuberculate ribs. Across venter ribs form loop between tubercles and on latter part of phragmocone form swollen band. Tuberculate ribs may also form swollen band on flanks. At whorl height of 10 mm tubercles may cover three ribs and be separated by only one or two intercalated ribs. Ribs on dorsum pass straight across and are weaker than on flanks. Between whorl height 14 mm and 26 mm ribs become more rectiradiate. At whorl height of 30 mm there are 11 ribs in a distance equal to whorl height.

Body chamber commences at whorl height of 32 mm. Tubercles become more widely spaced, covering 2–3 ribs being separated by up to 7 intercalated ribs. Last large tubercles occur at whorl height of 41 mm. Tubercles may become spinose on early body chamber, but progressively decrease in size adaperturally, covering only one rib but occurring on every rib. On body chamber ribs become almost rectiradiate; they become increasingly sinu-

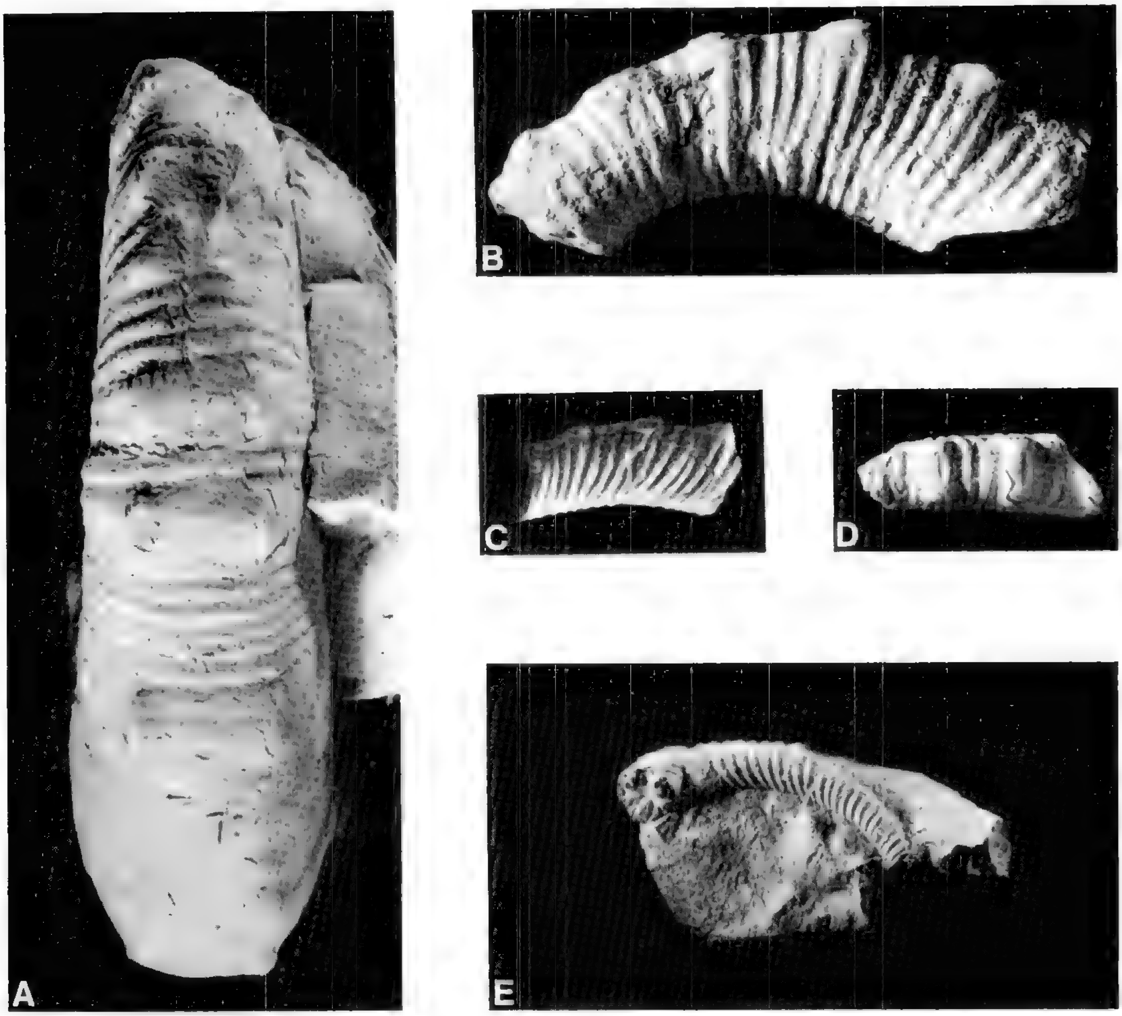

Fig. 5. *Protanisoceras auriculum* sp. nov.; A, GSSA M2416, holotype, ventral view; B, GSSA M2444, paratype, lateral view; GSSA M3547, paratype, C, lateral view, D, ventral view; E, GSSA M3550, lateral view. A, B, E from Algebuckina 17, 32 km SE of Oodnadatta; C, D from Toodla 8, 3 km SW of Mt Arthur; all Oodnadatta Formation, Middle Albian; all x 1.

soidal adaperturally. Body chamber reaches a maximum known whorl height of 50 mm.

Suture line with broad, bifid lateral lobe and small, trifid umbilical lobe, half width of lateral lobe; internal lobe trifid (Fig. 6B).

Discussion: Klinger (1976) has expanded the concept of *Protanisoceras* to include those forms which have tubercles spreading across more than one rib. This looped ornament, so well developed in *P. auriculum*, is seen in the European *loricatus* Zone (mid-Middle Albian) *P. nodosum* and *P. flexuosum* (d'Orbigny). *P. auriculum* can be distinguished from these species by its more elongate tubercles which extend over a greater number of ribs on the phragmocone, more prorsiradiate ribs and less ornamented body chamber. The Madagascar species *P. parcetuberculatum* Collignon (1962), like *P. auriculum*, possesses both single and looped ribs. It can be distinguished from *P. auriculum* by its narrower ribs and smaller tubercles.

Protanisoceras gracile sp. nov.

FIGS 6A, 7, 9D, E

Etymology: Latin—*gracilis*—slender.

1966 *Labeceras* (*Appurdiceras*) *cordycepoides* (Etheridge) (pars.); Ludbrook, p. 190.

1966 *Myloceras axonoides* (Etheridge) (pars.); Ludbrook, p. 44.

Holotype: GSSA M2455, from Oodnadatta Formation, Algebuckina 17 (5/571/17) (Ludbrook 1966), 27°49½'S, 135°34½'E, 32 km SE of Oodnadatta, on North Creek, near its junction with Neales River (OODNADATTA 1:250 000 geological map sheet).

Paratypes: GSSA M3558 from same locality as holotype and M3059 from Toodla 8, 3 km SW of Mt Arthur.

Other material: GSSA M2449, 3560–3567 from Algebuckina 17 and M3568–3569 from Toodla 8.

Age: Middle Albian.

Diagnosis: Coiling ancyloceratid; whorl section ovoid. Ventrolateral tubercles infrequent, occurring only on shaft and restricted to single ribs. Ribs prorsiradiate throughout, except on recurved hook where become rectiradiate adaperturally.

Description: Earliest known part of phragmocone with whorl height of 3 mm; moderately strongly coiled; with single, non-tuberculate, gently prorsiradiate ribs. Tubercles first appear at whorl height of 9 mm as small prominences either side of siphonal line. On early part of shaft tubercles occur on about every sixth rib. At whorl height of 10 mm ribs become sinuously prorsiradiate, more strongly inclined toward dorsum. Ribs thicker and more widely spaced along shaft. At whorl height of 12–14 mm small tubercles present on all ribs in some individuals, but less frequently, or not at all, on others. On recurved body chamber tubercles absent. Adaperturally ribs on body chamber wider and rectiradiate. Whorl section ovoid throughout shell with width 82% whorl height, with maximum whorl height on recurved body chamber of 19 mm. Suture line like that of *P. auriculum*.

Discussion: *P. gracile* can be easily distinguished from *P. auriculum* by its smaller size; possession of a shaft; weaker tuberculation; absence of looped ribs and slightly smaller lateral lobe. *P. gracile* is most similar to *P. nodosum* from the Middle Albian *loricatus* Zone in southern England in lacking lateral tubercles and having ventrolateral tubercles which do not occur on all ribs. *P. gracile* differs in its lack of looped ribs, tubercles which are not spinose, possession of more strongly prorsiradiate ribs and absence of tuberculation on the body chamber. *P. flexuosum*, also from the *loricatus* Zone, simi-

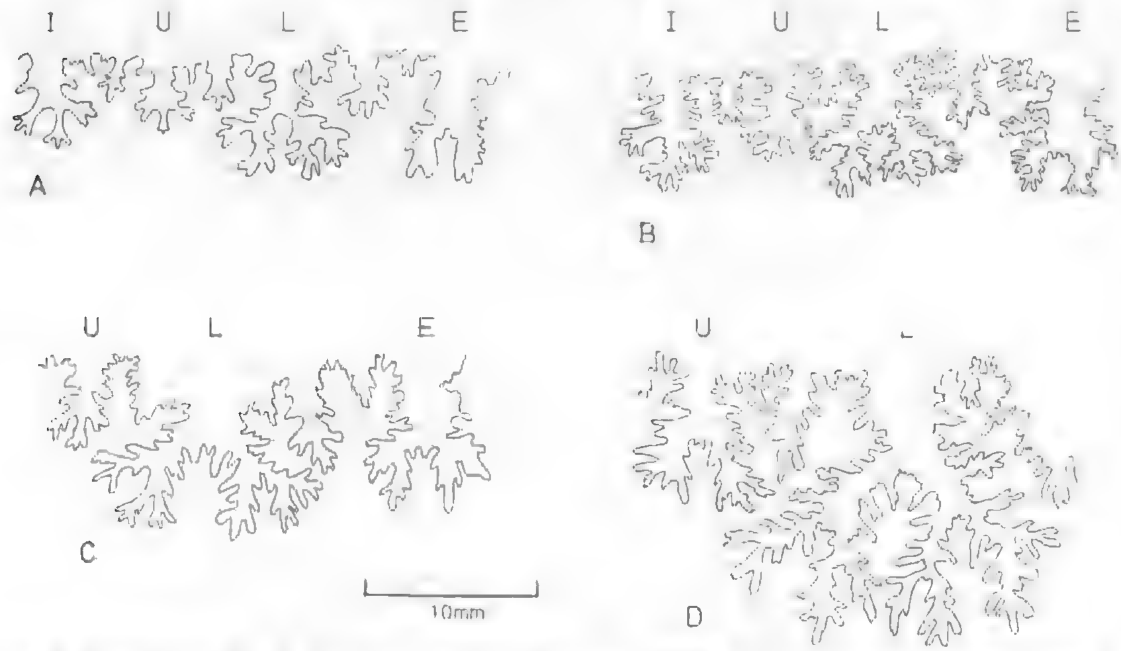

Fig. 6. Suture lines of: A, *Protanisoceras gracile* sp. nov., GSSA M2455, holotype, at whorl height of 12.5 mm; B, *P. auriculum* sp. nov., GSSA M3546, paratype, at whorl height of 16 mm; C, *Protanisoceras* sp. B, NMV P52327, at whorl height of 14 mm; D, *Anisoceras sweeti* sp. nov., NMV P52328, holotype, at whorl height of 23 mm. I — internal lobe; U = umbilical lobe; L — lateral lobe; E — external lobe.

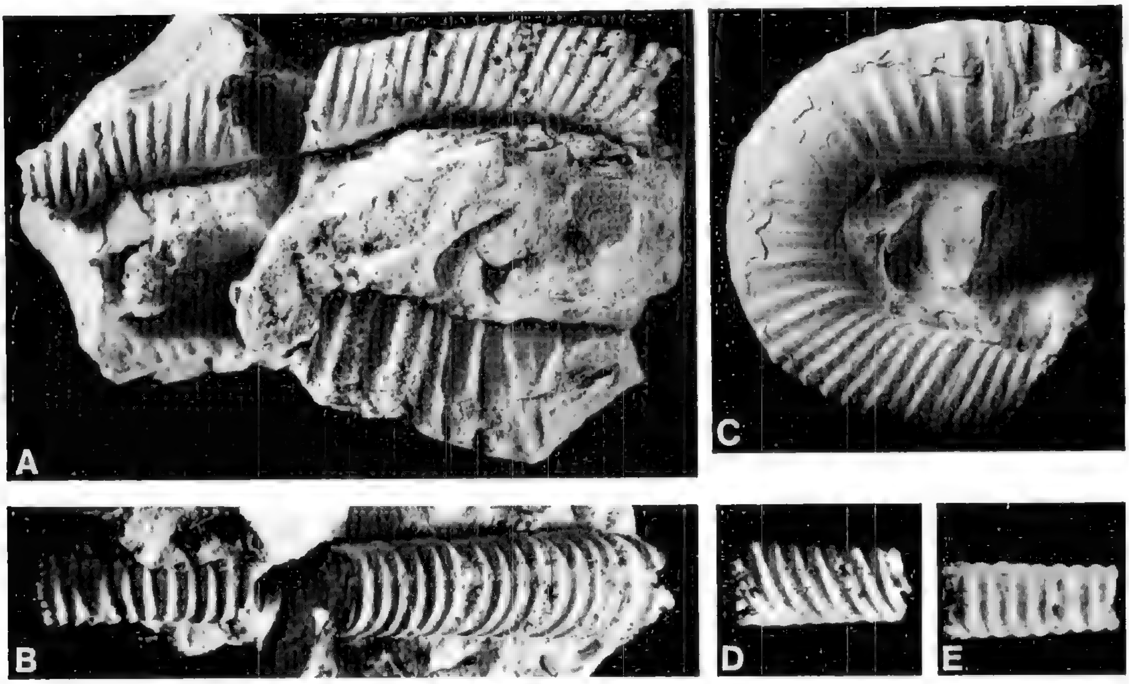

Fig. 7. *Protanisoceras gracile* sp. nov.; GSSA M2455, holotype, A, lateral view, B, ventral view; C, GSSA M3059, paratype, lateral view; GSSA M3558, paratype, D, lateral view, E, ventral view; A,B,D,E, from Algebuckina 17, 32 km SE of Oodnadatta, C from Toodla 8, 3 km SW of Mt Arthur; all from Oodnadatta Formation, Middle Albian; all x 1.

larly lacks lateral tubercles and possesses only small ventrolateral tubercles like *P. gracile*; however in *P. flexuosum* they occur more frequently.

P. gracile is similar to some species from the English Early Albian *mammillatum* Zone, such as *P. raulianum* (d'Orbigny), *P. cantianum* (Spath) and *P. blancheti* (Pictet & Campiche). These species, like *P. gracile*, possess only ventrolateral tubercles and lack looped ribs. However, *P. gracile* can be distinguished from these species by its more strongly prorsiradiate ribs. *P. gracile* resembles *P. gradatum* Collignon (1963, p. 40, Pl. 256, fig. 1101) from the Early Albian of Madagascar, but it is smaller and possesses more inclined ribs.

Protanisoceras aff. **gracile** sp. nov.

FIGS 8, 9F

Material and locality: One specimen, GSSA M2441, from Oodnadatta Formation, Algebuckina 17 (5/571/7), 32 km SE of Oodnadatta (OODNADATTA 1:250 000 geological sheet map).

Age: Middle Albian.

Remarks: This specimen, consisting of the latter part of the shaft and the recurved body chamber, differs from *P. gracile* in the possession of tubercles which extend across two ribs on the latter part of the phragmocone. Like *P. gracile* the body chamber lacks tuberculation; however, the tighter recurving of the body chamber has resulted in the umbilical bifurcation of some ribs. In terms of whorl section and size this specimen conforms with *P. gracile*, but its more strongly developed tuberculation and tighter recurving are distinctive.

Protanisoceras sp. A

FIGS 9G, 10A, B

Material and locality: An incomplete shaft, NMV P60543, from "Primrose Springs, Peake Station".

Age: Middle Albian.

Description: Whorl section circular with diameter of 16 mm. Ribs slightly prorsiradiate; each rib bears small ventrolateral and lateral tubercle. Tubercles cover only single rib. There are eight ribs in a length equal to whorl diameter.

Discussion: This form can be easily distinguished from *P.* sp. B by the absence of looped ribs with tubercles covering more than one rib.

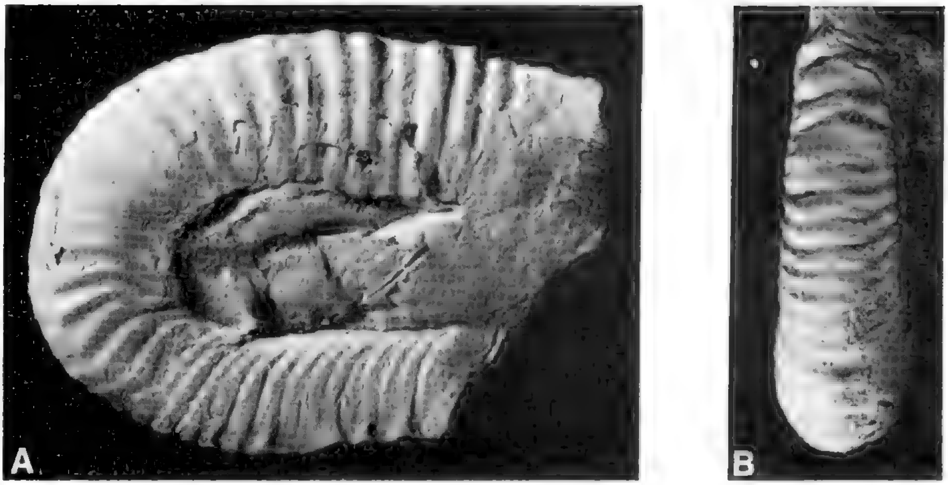

Fig. 8. *Protanisoceras* aff. *gracile* sp. nov.; GSSA M2441, A, lateral view, B, ventral view; from Algebuckina 17, 32 km SE of Oodnadatta; Oodnadatta Formation, Middle Albian; both x 1.

The absence of suture and the impression of the dorsum of the phragmocone on the matrix attached to the specimen indicate that the specimen is the recurved body chamber. It is a much longer body chamber than possessed by other Australian species of *Protanisoceras* of similar size. The ribbing is finer and more closely spaced than seen in English Early-Middle Albian species. The Middle Albian *P. cantianum* Spath (1939) from southern England has a similar whorl section and tuberculation, but it possesses thicker, more widely spaced ribs.

Protanisoceras sp. B

FIGS 6C, 9H, 10C, D

Material and locality: A single, incomplete phragmocone, NMV P52327, from "Primrose Springs, Peake Station".

Age: Middle Albian.

Description: This specimen, an incomplete, largely internal mould of the latter part of the phragmocone, is characterised by possession of large ventrolateral and lateral tubercles of similar size. Tubercles connected by looped ribs and extend across three ribs; separated by 0–2 intercalated non-tuberculate ribs. Whorl section is semicircular. This form particularly characterised by large, bifid lateral lobe (Fig. 6C) which is almost half as wide again as first saddle; it is four times wider than trifid umbilical lobe.

Discussion: Specimens of *Protanisoceras* described by Klinger (1976) from Zululand also possess both ventrolateral and lateral tubercles. However, in all the forms Klinger described the tuberculate ribs are much more widely separated by non-tuberculate ribs than in the S.A. forms. *P.* sp. B compares with some English Late Albian species of *Anisoceras*, such as *A. armatum*, in the nature of the tuberculation; however, whereas species of *Anisoceras* possess a bifid umbilical lobe it is trifid in *P.* sp. B. The ornamentation is like that of *A. sweeti*. The two species can be distinguished by the nature of the umbilical lobe and the smaller size of *P.* sp. B. This species differs from *P. auriculum* and *P. gracile* in its possession of lateral tubercles.

Family **HAMITIDAE** Hyatt 1900

HAMITES Parkinson 1811

Type species: Hamites attenuatus J. Sowerby 1814, by subsequent designation of Diener 1925, p. 65.

Hamites cf. **attenuatus** J. Sowerby 1814

FIG. 11

Material and localities: A complete body chamber, NMV P52336 from "Primrose Springs, Peake Station", and an incomplete body chamber, GSSA M2447, Oodnadatta Formation, Algebuckina 17 (5/571/17).

Age: Middle Albian.

Remarks: The well preserved body chamber has an almost circular whorl section. Like *H. attenuatus* from the Middle Albian *dentatus*-

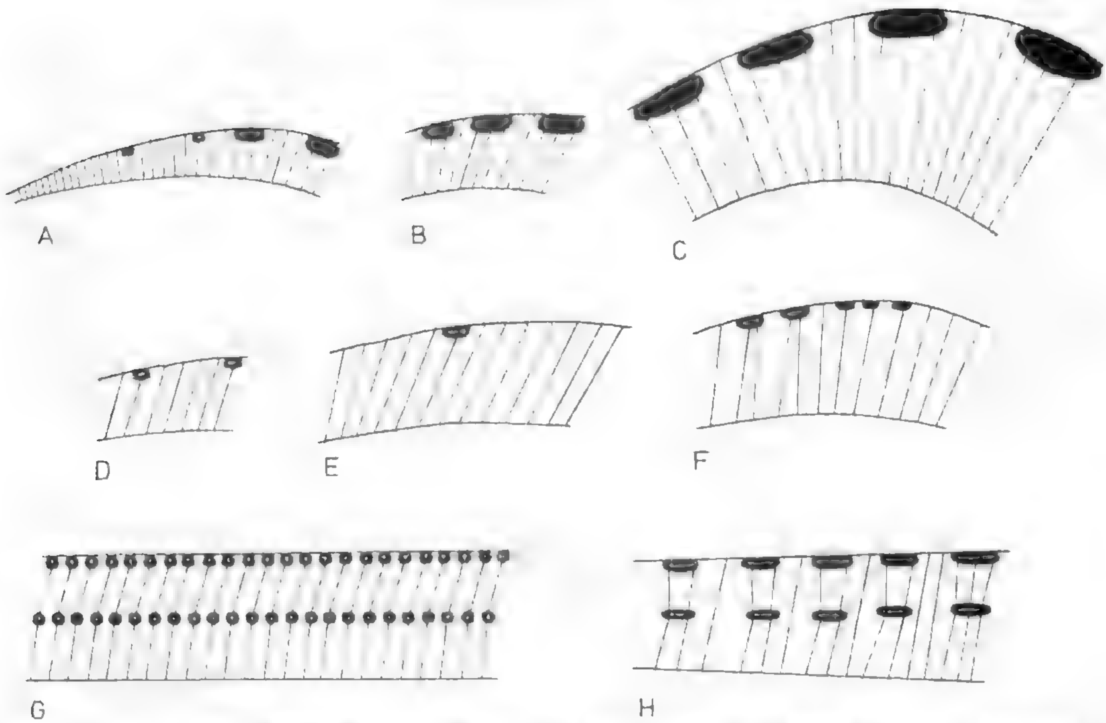

Fig. 9. Diagrammatic representation of variation in distribution of ribs and tubercles in species of *Protanisoceras*. A–C, *P. auriculum* sp. nov., A, GSSA M3550, B, GSSA M3547, paratype, C, GSSA M2444, paratype; D–E, *P. gracile* sp. nov., D, GSSA M3558, paratype, E, SADM M2455, holotype, F, *P.* aff. *gracile* sp. nov., GSSA W2441, G, *P.* sp. A, NMV P60543; H, *P.* sp. B, NMV P52327. All natural size.

loricatus Zones of southern England, the S.A. form possesses ribs which are slightly prorsiridiate prior to the hook; rectiradiate on the hook, becoming initially rursiradiate on the recurved shaft, then finally rectiradiate. Similarly it has 7–8 ribs in a length equal to the whorl diameter. The whorl section of the English form is said to be slightly laterally compressed (Spath 1939) whereas it is slightly dorsoventrally compressed in the S.A. form.

In both forms the adapertural part of the body chamber curves away from the phragmocone. The impression of the dorsum of the phragmocone against the body chamber (Fig. 11A) shows that the body chamber was deflected away from the phragmocone during growth as the two shafts came into contact.

The suture line of the S.A. form is of similar proportions to the English form, with a bifid lateral lobe and small trifid umbilical lobe. Whitehouse (1926) described a form from the Albian of Qld which he called *H.* aff. *maximus* J. Sowerby. This specimen, as can be seen in Whitehouse's figure, possesses a trifid lateral lobe, whereas in *Hamites* it is bifid; it is thus not a species of *Hamites*.

Age of the ammonites

The Marree Subgroup comprises the Aptian Bulldog Shale and the Albian Oodnadatta Formation (Freytag 1966, Ludbrook 1966, 1978, 1980). Since Ludbrook's (1966) biostratigraphical study was submitted for publication, the OODNADATTA 1:250 000 geological map sheet has been published (Freytag *et al.* 1967) and the rock units comprising the Aptian-Albian sequence named in some detail (Freytag 1966). It is now possible to relate the ammonites to the rock units, as mapped on the OODNADATTA and adjoining sheets, from which most of them were collected.

The ammonite *Sanmartinoceras* (*Sinzovia*) *fontinale* from the Marree Subgroup at 'Primrose Springs, Peake Station' was described by Hudleston (1890). Thomson (1974) discussed the range of *Sanmartinoceras* and believed that it is, by and large, an Aptian form. The occurrence of *S.* (*Sinzovia*) in association with *Tropaeum* in Qld led Day (1969) to conclude

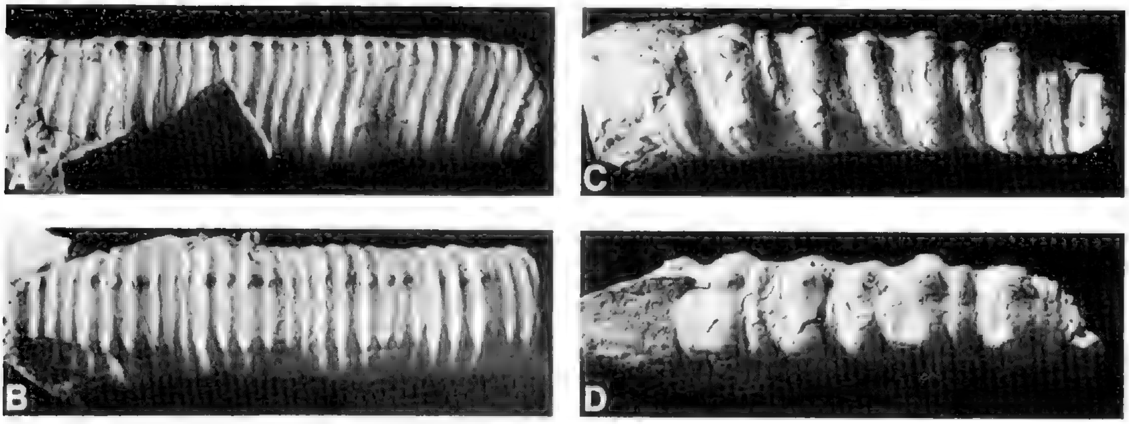

Fig. 10. *Protanisoceras* sp. A; NMV P60543, A, lateral view, B, ventral view. *Protanisoceras* sp. B, NMV P52327, C, lateral view, D, ventral view. Both from "Primrose Springs, Peake Station"; Oodnadatta Formation, Middle Albian, both x 1.

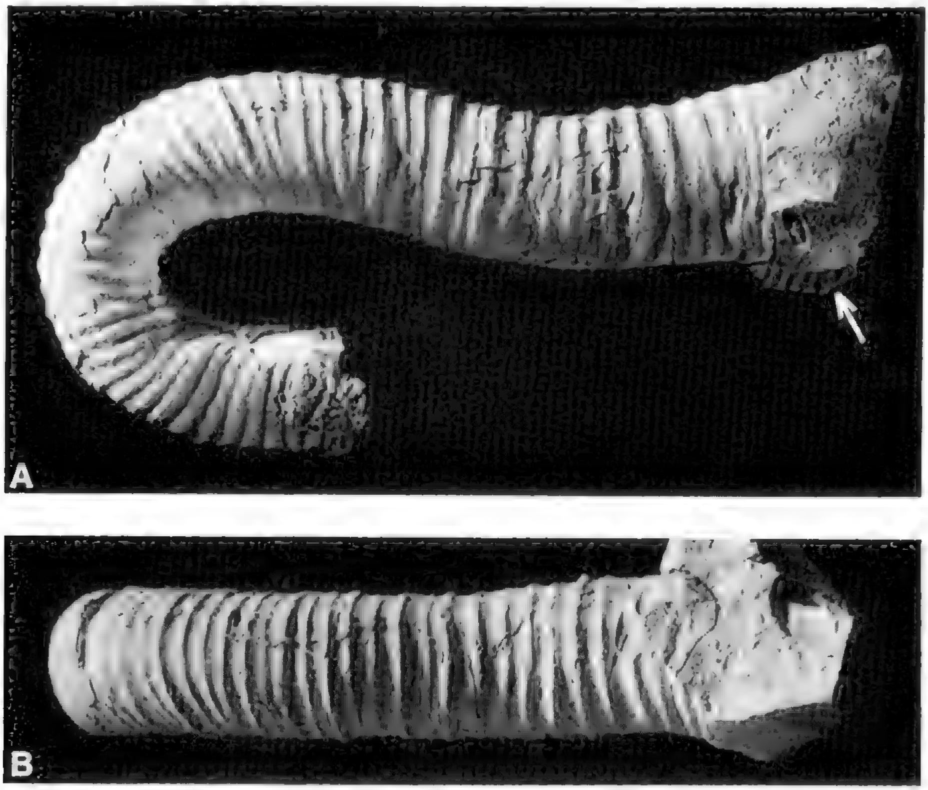

Fig. 11. *Hamites* cf. *attenuatus* J. Sowerby 1814; A, lateral view, B, ventral view; from "Primrose Springs, Peake Station"; Oodnadatta Formation, Middle Albian; x 1. Arrow indicates impression of dorsum of part of phragmocone.

a Late Aptian age for the genus in Australia. A Late Aptian age for part, at least, of the Bulldog Shale is further indicated by the presence of *Tropaeum* in S.A. (Howchin & Whitehouse 1928).

In her biostratigraphical study of the Cretaceous rocks of the Great Artesian Basin in S.A. Ludbrook (1966) concluded that there was no reliable means of establishing a detailed biostratigraphic zonation of the

Marree Subgroup between the Late Aptian and Late Albian on the evidence of ammonites. Part of the reason for this has been the attribution of any small heteromorph ammonite found in the formation to the Late Albian genera *Myloceras* or *Labeceras* (e.g. Ludbrook 1966), although it has now been shown that a number of other genera are present. It also stems from the inaccurate statement of Brunnschweiler (1959) who, in describing species of *Falciferella* from the Santos Oodnadatta No. 1 Well, stated, "The beds from the surface down to about 375 feet contain also *Myloceras, Labeceras, Appurdiceras, Boliteceras* etc., and are to be regarded as early Upper Albian . . ."; *Falciferella* he recorded between 71.5 m (235 ft) and 113.3m (372 ft). This led Brunnschweiler to conclude that *Falciferella* was of Late Albian age in Australia (even though it is restricted to the Middle Albian *intermedius* and *niobe* Subzones of the *loricatus* Zone in England (Owen 1971)) as the *Labeceras–Myloceras* fauna in Qld, Madagascar and Zululand has been established as Late Albian (Whitehouse 1926, Klinger 1976, McNamara 1978). However, as Ludbrook (1966) has noted, this Late Albian fauna does not occur with *Falciferella* in the Oodnadatta No. 1 Well. Brunnschweiler was probably referring to the Late Albian ammonite fauna at Fossil Creek (Reyment 1964 a,b).

Ludbrook (1966) placed the "unnamed greensand member" (now the Coorikiana Member of the Oodnadatta Formation), which occurs in Santos Oodnadatta No. 1 Well between 131 and 137 m, at the base of the Albian. She records *Falciferella* in the well between this member and the top of the Oodnadatta Formation, which is thought to be of Late Albian age (Ludbrook 1978), at about 91 m. This is suggestive of a Middle Albian age for *Falciferella* in Australia as in England.

Cooper & Kennedy (1979) have recently placed the two described Australian species *F. breadeni* and *F. reymenti*, in the binneyitid *Borissiakoceras*, which, apart from an incomplete specimen from the uppermost Albian of Angola, is restricted to the Late Cenomanian to Early Turonian (Wright *in* Arkell *et al.* 1957). Cooper & Kennedy consider that there is a direct phylogenetic relationship between the Middle Albian *Falciferella*, with its falcoid growth lines and ribs, and the almost smooth *Borissiakoceras*. Following Brunnschweiler's assignment of a Late Albian age to *F. breadeni* and *F. reymenti*, Cooper & Kennedy suggested that these species may belong in *Borissiakoceras*. However, these species, like the type species of *Falciferella*, *F. millbournei* Casey (1954), have fine ribs on the body chamber, and a trifid lateral lobe, which in *Borissiakoceras* is bifid (Cobban 1961). Examination of the type and topotype material of *F. breadeni* from the Oodnadatta Formation, revealed the suture line to be more crenulate than shown by Brunnschweiler (1959), being very close to that of *F. millbournei*. Furthermore the occurrence of *F. breadeni* and *F. reymenti* with the Middle Albian species of *Protanisoceras* (see below) and a Middle Albian species of *Hamites*, and possessing ribbing which is more akin to *Falciferella* than to *Borissiakoceras*, suggest that Brunnschweiler's original emplacement in *Falciferella* is more appropriate. Obviously there is a close relationship between these two genera, sufficient for Kennedy & Juignet (1973) to have placed *Falciferella* in the Binneyitidae and not the Oppeliidae as did Wright (*in* Arkell *et al.* 1957).

At Algebuckina 17 *Falciferella* occurs (Ludbrook 1966) with *Protanisoceras auriculum* and *P. gracile*. Species of *Protanisoceras* also occur at "Primrose Springs, Peake Station". *Protanisoceras* was considered by Wright (*in* Arkell *et al.* 1957) to range from the Early-Middle Albian. The youngest species in the English Middle Albian occurs in the *intermedius* Subzone of the *loricatus* Zone (Owen 1971). Klinger (1976) extended its lower range into the Late Aptian. Casey (1961) has shown that the earliest English Albian species of *Protanisoceras*, which appear in the *floridum* Subzone of the *mammillatum* Zone, compare closely with contemporaneous species of *Hamites*, differing only in the development of small ventrolateral tubercles which cover single ribs. In the succeeding *raulianum* and *puzianus* Subzones there is a general trend toward increasing tuberculation, the species possessing more frequent and prominent ventrolateral tubercles and the development of lateral tubercles; these species coexist with poorly tuberculate species. In the early Middle Albian *dentatus* and early *loricatus* Zones (Spath 1939) species with lateral tubercles predominate, and an increasing number of species, such as *P. nodosum* and *P. flexuosum* of the *loricatus* Zone (Owen 1971), have looped ribs. In these later species there is a loss of lateral tubercles, as occurs in *P. auriculum* and *P. gracile*.

The occurrence at Algebuckina 17 of species of *Protanisoceras* morphologically closest to the *loricatus* Zone species, coexisting with species of *Falciferella*, which occurs only in the first two subzones of the *loricatus* Zone (Owen 1971), and with *Hamites* cf. *attenuatus*, which ranges from the late *dentatus* Zone through the *loricatus* Zone, suggests that this part of the Oodnadatta Formation may correlate with the mid-Middle Albian *loricatus* Zone of the Anglo-Paris Basin.

The locality cited as "Primrose Springs, Peake Station" in the old literature probably includes more than one locality, as stated above. Until the WARRINA 1:250 000 geological map sheet is mapped in detail, it will not be possible to identify the precise localities from which the Late Aptian *Sanmartinoceras (Sinzovia) fontinale*, and the Middle Albian species of *Protanisoceras* with looped ribs and *Hamites* cf. *attenuatus*, were collected. In addition, the occurrence of *Anisoceras sweeti* indicates that younger strata also outcrop in this region, as the genus ranges from the Late Albian to the Late Turonian (Wright *in* Arkell *et al.* 1957). As the Blanchewater Formation which overlies the Marree Subgroup in the Marree area is thought to be latest Albian in age, possibly extending into the Cenomanian (Ludbrook 1966, 1978), the upper part of the Oodnadatta Formation is early Late Albian in age. This has been established at Fossil Creek by the presence of *Myloceras* and *Labeceras*.

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AGES AND ASHES IN LAKE FLOOR SEDIMENT CORES FROM VALLEY LAKE, MT GAMBIER, SOUTH AUSTRALIA

BY C. E. BARTON & M. W. MCELHINNY

Summary

A set of our cores from Valley Lake shows a sequence of fresh water organic muds above a band of argonite 8-10 cm thick, overlying a graded calcareous tuff. Magnetic remanence and susceptibility measurements indicate the absence of volcanic episodes since the onset of deposition of the organic muds 5000 to 6000 years ago. Radiocarbon ages of ~14 000 years and ~38 000 years for the aragonite band and the tuff respectively are not considered to reflect their ages of formation.

AGES AND ASHES IN LAKE FLOOR SEDIMENT CORES FROM VALLEY LAKE, MT GAMBIER, SOUTH AUSTRALIA

by C. E. BARTON*† & M. W. MCELHINNY*

Summary

BARTON, C. E. & MCELHINNY, M. W. (1980) Ages and ashes in lake floor sediment cores from Valley Lake, Mt Gambier, South Australia. *Trans. R. Soc. S. Aust.* **104**(6), 161-165, 28 November, 1980.

A set of four cores from Valley Lake shows a sequence of fresh water organic muds above a band of aragonite 8–10 cm thick, overlying a graded calcareous tuff. Magnetic remanence and susceptibility measurements indicate the absence of volcanic episodes since the onset of deposition of the organic muds 5000 to 6000 years ago. Radiocarbon ages of ~14 000 years and ~38 000 years for the aragonite band and the tuff respectively are not considered to reflect their ages of formation.

Introduction

Valley Lake (37° 51′S, 140° 46′E) is the second largest of the four lakes in the Recent volcanic craters at Mount Gambier, South Australia. Chemical and biological aspects of the lake have been described by Bayly & Williams (1964), and the morphology and benthos by Timms (1974). The lake is now fresh and at a level considered to be controlled by the ground water table.

The geology of the Mt Gambier complex has received considerable attention, the most recent being a detailed study by Sheard (1978) which includes a review of the previous work. In Sheard's reconstruction the two larger lakes, Blue Lake and Valley Lake occupy open craters called maars, formed by volcanic explosions, as do the smaller lakes, Brownes Lake and Leg of Mutton Lake.

Two charcoal samples picked from soils beneath tuff layers have been radiocarbon dated. The first was collected by C. G. Stephens in the township of Mt Gambier and dated at 4830 ± 70 BP (Gill 1955; Fergusson & Rafter 1958), and the second was collected 4 miles away to the SSE and dated at 1410 ± 90 BP (Blackburn 1966). Blackburn was of the opinion that these dates may represent separate volcanic episodes, and this view has also been adopted by Sheard (1978).

Four cores were recovered in 54 mm (class 12) PVC tubes using a 6 m Mackereth corer (Mackereth 1958): VB in 16 m of water from the deepest part of the lake, and VA, VC and VD in 14.5 m of water from the flattish area about 50 m NE of the deepest part (see Timms (1974) bathymetric chart). Echo soundings showed small scale variations in bottom topography not resolved in Timms' chart; cores were collected as close as possible from the hollows.

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Core descriptions

All four cores displayed the same features: approximately 1 m of black fresh-water organic muds, above a very clearly defined 8–10 cm band of extremely fine grained creamy white aragonite, overlying a graded column of calcareous tuff. VD achieved the maximum penetration through the tuff and is pictured in Figure 1.

Shells are abundant in the organic muds and were identified by B. J. Smith as ". . . assemblages of ostracod shells and the small freshwater bivalve *Pisidium* sp. These are found in fresh waters low in dissolved salts and usually permanent."

X-ray analysis of the creamy white band performed by J. Caldwell of A.N.U., gave a composition of 95% aragonite + 5% low magnesium calcite. Under the microscope much of the material consisted of rods ~1 μm in length. Diatoms were common and, in contrast to the underlying tuff, there was a marked absence of quartz and ferromagnesian (opaque) minerals.

The graded tuff was rich in carbonates with some euhedral rhombs (calcite/dolomite) but mainly irregular fragments. Volcanic glass, angular with inclusions of crystallites and gas bubbles, was common. Quartz grains, usually fairly well rounded, were present together with a scattering of microfossils.

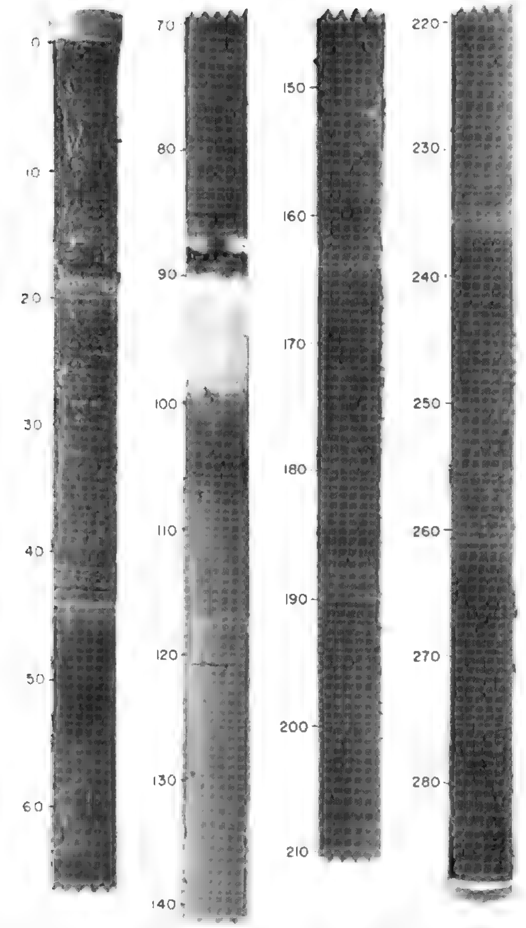

Fig. 1. Photocomposite section through Valley Lake core VD. Distances from top of core given in cm.

Evidence of horizontal bedding occurred in the top 10 cm of the tuff column, but otherwise the material appeared to have been rapidly deposited under water. The boundary with the aragonite band was less abrupt than that between the organic muds and the aragonite, but nevertheless quite sharp, as can be gauged from the photograph.

J. R. Dodson examined samples from the aragonite band and the upper calcareous tuff for pollen grains. In the aragonite there were plenty of grains, particularly *Casuarina* and *Eucalyptus* with some aquatic taxa, whereas the tuff contained very few grains: a scattering of *Casuarina* and *Eucalyptus* but no *Compositae*. Although insufficient material was examined to provide a definitive conclusion, these assemblages are consistent with a Holocene age for the aragonite and preclude an age greater than 15 000 BP for the deposition of the tuff, which must have occurred rapidly (Dodson pers. comm.).

Magnetic results

Measurements of the horizontal natural remanent magnetisation (NRM) were made at 1 cm intervals along the length of each complete core using an automated version (Barton 1978)[1] of the "Digico" whole core spinner magnetometer (Molyneux *et al.* 1972). VD was sliced open, subsamples were extracted in adjacent pairs of perspex cube shaped pots (volume 5.3 cm^3) every 2.5 cm, and measured on a cryogenic "SQUID" magnetometer (Goree & Fuller 1976).

All cores yielded mutually consistent results, showing a large contrast in NRM intensity between the organic muds (typically 0.5–1.5 $mA.m^{-1}$) and the calcareous tuffs (typically 100–180 $mA.m^{-1}$) as illustrated in Figure 2. A well dated magnetic secular variation pattern exists for SW Victoria covering the last 1000 years based on the magnetic remanence of sets of cores from L. Keilambete, L. Bullenmerri and L. Gnotuk (Barton[1]). Unfortunately, the directional results from Valley Lake (Fig. 2) are too scattered to permit magnetic dating. Magnetic cleaning in an alternating magnetic field (AF) of peak value 15 mT failed to reduce the scatter. Median demagnetising fields (i.e. the peak AF required to halve the initial remanence) for 8 specimens distributed throughout core VD ranged from 2 to 6.5 mT, which is too low to sustain a stable primary remanence. The high water content in the organic muds (85–90% by weight) certainly contributes to this instability.

Initial susceptibility measurements on core VD (Fig. 3) reflect a contrast of about 3 orders of magnitude between the organic muds and the calcareous tuffs. Much of the organic mud is weakly diamagnetic, i.e. the susceptibility is negative.

Radiocarbon dating

An initial radiocarbon age of 38 400 BP on the total organic fraction from VD 107–117 cm prompted a more detailed investigation into the chronology of these cores. The results are given in Table 1. Both the calcareous tuff

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[1] Barton, C. E. (1978) Magnetic studies of some Australian Lake Sediments. Ph.D. thesis (unpubl.), Australian National University, Canberra.

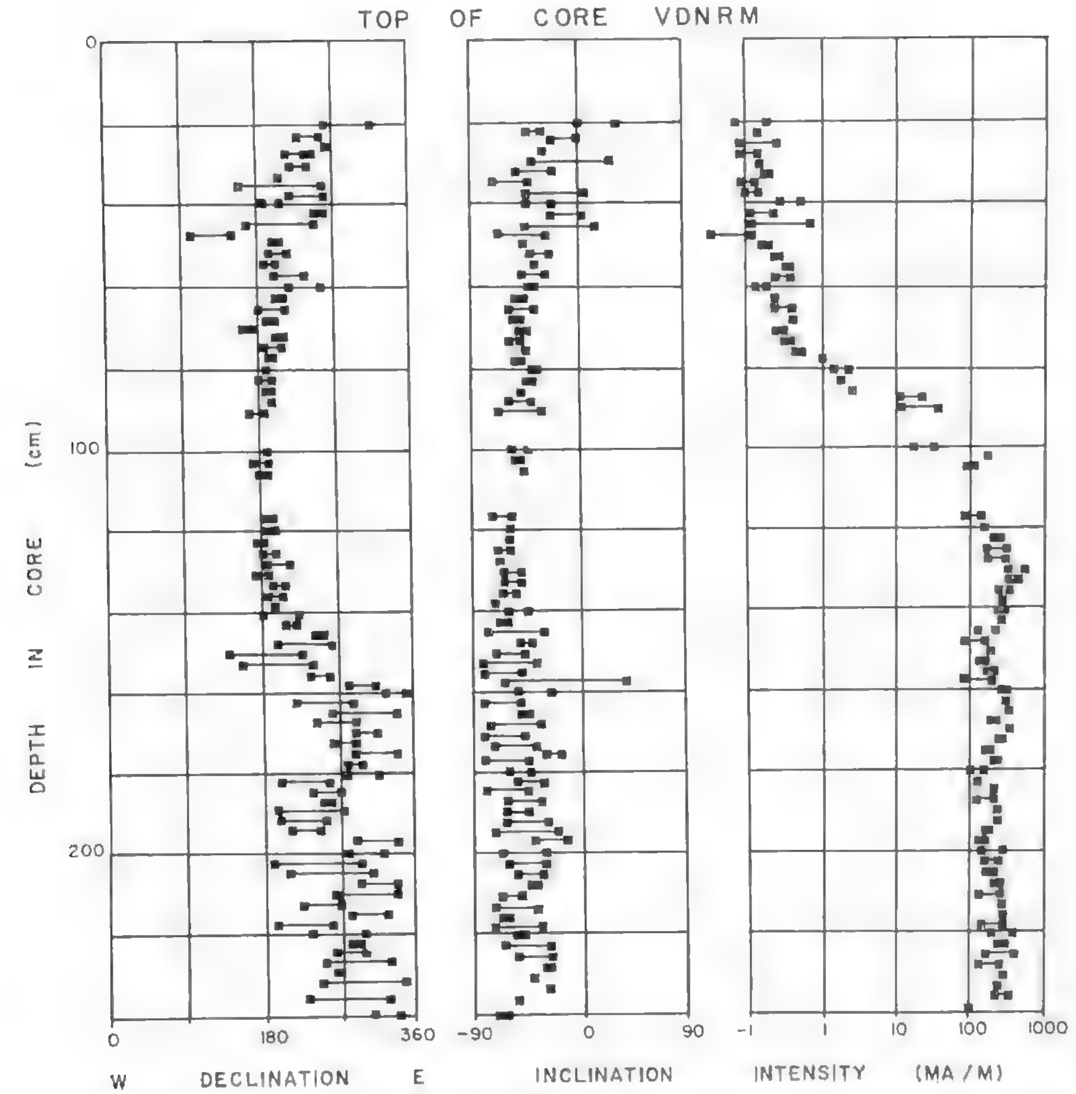

Fig. 2. NRM results for core VD. Vertical grid interval (bar spacing) is 20 cm; pairs of measurements at same stratigraphic level linked by lines. Above 20 cm core was too wet to be subsampled; whole core measurements showed that intensity remained low in this zone.

and the aragonite band yielded barely sufficent organic carbon to obtain a date, hence the large counting uncertainties. A carbonate date was obtained for the aragonite band in VA.

Radiocarbon ages are plotted against the equivalent distance from the top of VB in Figure 4. Correlation between VD and VB for sample ANU 1809 is based on equal sedimentation rates within the tuffs and may therefore be in error by up to say ± 5 cm; there can be no uncertainty about the equivalent position in VB of the aragonite band, sample ANU 2051.

Within the organic muds, the monotonic ^{14}C age sequence is consistent with uniform deposition since 6000 BP. The fact that the ^{14}C ages within the organic muds plotted in Figure 4 extrapolate to near the origin is taken to indicate the absence of any major systematic increase in ages due to the incorporation of ancient carbon (from say, the Miocene limestone basement which outcrops around parts of the lake). Although further age determinations are really requred to confirm this, it is worth noting that no systematic age increases in excess of a few hundred years have been

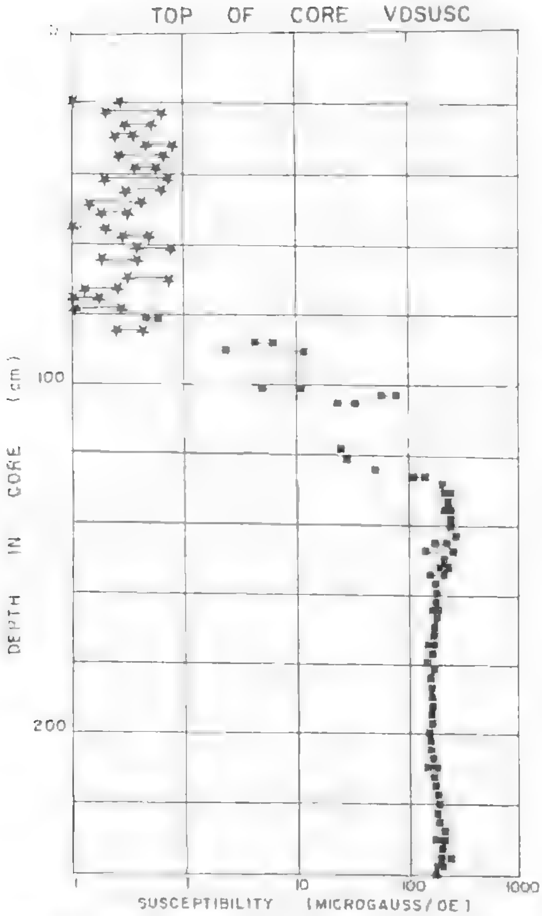

Fig. 3. Initial susceptibility results for core VD. Format of plot is as for Fig. 2 except that negative (diamagnetic) susceptibilities plotted as positive with X instead of square. Much of upper 80 cm of organic muds diamagnetic. Volume susceptibility of 1 Gauss Oersted^{-1} in cgs equivalent to 4π in SI system and dimensionless.

found in sequences from L. Keilambete, L. Bullenmerri and L. Gnotuk in SW Victoria (Bowler & Hamada 1971; Barton & Polach 1980). These lake sediments have been intensively dated by radiocarbon and are from similar geological environments to Valley Lake.

Ages of eruption

The graded calcareous tuff has every appearance of having been rapidly deposited in a single episode into a lake containing at least 1–2 m water. Excluding the possibility that this occurred 38 000 years ago, which is inconsistent with previous age determinations, the pollen data, and the morphology of the Mt Gambier complex, there must be considerable amounts of ancient organic carbon (charcoal) incorporated in the tuff to account for such an age.

Intensive radiocarbon analysis of magnetically correlated cores of organic mud from Bullenmerri, 38°15′S, 143°06′E (Barton[1]; Barton & Polach 1980) indicates a 25% probability of >20% anomalies in radiocarbon ages. These muds are not dissimilar from those in Valley Lake. Although these figures overestimate the dating uncertainties in many lacustrine sequences, e.g. Keilambete, 38°13′S, 142°52′E, (Bowler & Hamada 1971; Barton & Polach 1980), they should nevertheless be regarded as a guide in assessing the significance of isolated ^{14}C determinations. Hence the 6180 ± 80 BP age at the bottom of the organic muds is not necessarily inconsistent with an eruption age of 4800 BP.

Magnetic intensity and susceptibility contrasts between the organic muds and the tuffs provide a sensitive measure of the presence of volcanic ejecta within the sequence. At no point within the organic muds do either of these

Table 1. *Conventional radiocarbon ages for samples from three Valley Lake cores. All determinations, with the exception of that marked *, are made on total organic fractions.*

ANU Sample number	Depth in Core (cm)	Equivalent Depth in VB (cm)	^{14}C age ± 1 SD	Comment
ANU 2125	VB 40–50	40–50	2960 ± 90	Organic mud
2126	VB 80–90	73–83	3960 ± 80	Organic mud
2052	VB 110–120	103–113	6180 ± 80	Organic mud
2051	VA 117–122	114–122	13900 ± 370	Aragonite (organic)
			15450 ± 160*	Aragonite (inorganic)
1809	VD 107–151	141–151	38400 + 2070) 1640)	Calcareous tuff

* total inorganic fraction

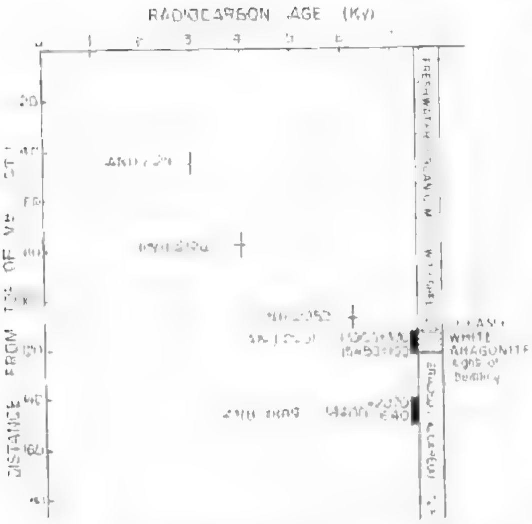

Fig. 4. Conventional radiocarbon age-depth plot for core VB together with simplified log of core. Ages expressed in units of 1000 years (Ky). Vertical error bars denote sample lengths and horizontal ones, 1 standard deviation counting uncertainties in ages. Samples ANU 2051 and ANU 1809, taken from cores VA and VD respectively, marked at their equivalent distances from top of core VB.

parameters even remotely approach the high values within the tuffs, nor is there any evidence to the naked eye of a volcanic interlude. It is therefore concluded with some confidence that no eruption has occurred near the lake since the deposition of the calcareous tuffs.

The problem remains as to the significance of the organic and inorganic ages of 14 000 years for the aragonite band. Sufficiently slow deposition of aragonite could explain the 6000 year time break at the upper boundary indicated by the average age of the whole band. However, since the organic muds indicate fresh water conditions throughout the last 5000 to 6000 years, it is considered improbable that conditions under which only 95% pure aragonite was deposited could have existed within the lake for many thousands of years previously. The preferred conclusion, and one which is more consistent with the geological evidence, is that the aragonite was produced fairly rapidly at the end of the eruptive phase at 5000 BP or possibly 6000 BP, and that both ages reflect the presence of dead carbon derived from the volcanic ejecta or from stirring of the original lake floor.

Acknowledgments

We thank the Corporation of the City of Mt Gambier for granting access to the lake and for providing storage facilities and information, Dr B. J. Smith (National Museum of Victoria) for shell identification, and Dr J. R. Dodson (University of New South Wales) for pollen identification.

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AMINO ACID RACEMIZATION DATING OF LATE QUATERNARY STRANDLINE EVENTS OF THE COASTAL PLAIN SEQUENCE NEAR ROBE, SOUTHEASTERN SOUTH AUSTRALIA

BY C. C. VON DER BORCH, J. L. BADA & D. L. SCHWEBEL

Summary

The amino acid racemization dating technique has been applied to three selected mollusc samples collected from the Quaternary strandline sequence of southeastern South Australia. Results of the study are consistent with previous uranium-series age determinations in the area and imply that at least the uppermost component of the Woakwine Range barrier-estuarine sequence was emplaced during the last interglacial sealevel maximum around 125 000 years ago.

AMINO ACID RACEMIZATION DATING OF LATE QUATERNARY STRANDLINE EVENTS OF THE COASTAL PLAIN SEQUENCE NEAR ROBE, SOUTHEASTERN SOUTH AUSTRALIA

by C. C. VON DER BORCH,* J. L. BADA,† & D. L. SCHWEBEL‡

Summary

VON DER BORCH, C. C., BADA, J. L. & SCHWEBEL, D. L. (1980) Amino acid racemization dating of Late Quaternary strandline events of the coastal plain sequence near Robe, southeastern South Australia. *Trans. R. Soc. S. Aust.* **104**(6), 167-170, 28 November, 1980.

The amino acid racemization dating technique has been applied to three selected mollusc samples collected from the Quaternary strandline sequence of southeastern South Australia. Results of the study are consistent with previous uranium series age determinations in the area and imply that at least the uppermost component of the Woakwine Range barrier-estuarine sequence was emplaced during the last interglacial sealevel maximum around 125 000 years ago.

Introduction

Oxygen isotope studies of deep-sea pelagic sediments, combined with magnetostratigraphy and other dating techniques (Shackleton & Opdyke 1976; Hays *et al*, 1976), have established a relatively detailed chronology of Quaternary glacial and interglacial stages. Related eustatic sealevel oscillations recorded as stranded shoreline deposits on continental margins are currently under scrutiny. Although more difficult to date, they serve as an independent check on some of the deep sea data. In addition, the establishment of an acceptable chronology for Quaternary and older shoreline sequences is of foremost interest from a geodynamics point of view. A correctly dated succession of terraces can reveal the temporal variation in uplift rate of convergent plate boundaries such as island arcs, and mid-plate tectonic movements such as regional warping on passive margins. It is of interest to establish acceptable chronologies from coastal strandline sequences from a variety of tectonic settings and areas.

The coastal plain of southeastern South Australia (Fig. 1) is characterized by what may be one of the most complete and best preserved sequences of Quaternary strandlines in existence. At least 20 emergent shorelines, consisting of stranded calcareous sand barriers and associated lagoonal and lacustrine deposits, occur in a region 90 km wide by about 400 km long (Fig. 1). A sequence of less obvious siliceous sand beach ridges of Plio-Pleistocene age (not shown in Fig. 1) extends for a further 100 km east of the Naracoorte Range into the State of Victoria (Hills 1960; Blackburn *et al.* 1967).

The calcareous strandlines shown in Figure 1 owe their preservation to a combination of

Fig. 1. Coastal Plain, southeastern South Australia, showing Quaternary strandlines; section X-Y refers to Figure 2.

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factors, the dominant of which has been gentle regional upwarping of the coastal plain throughout the Quaternary, centred on the volcanic region in the extreme southeast of the state (Hossfeld 1950; Sprigg 1952). This upwarping has been responsible for the stranding of the sequence, in which oldest shorelines in general lie furthest inland. Preservation of these strandline features has been due largely to rapid "case-hardening" of the calcareous barrier facies sands by extensive calcrete development which generally begins immediately the sands become stabilized by vegetation. Only high sealevels are represented in the record, due to a combination of relatively slow uplift rate and the dynamics of sediment transport as sea level rises from a low stillstand.

In common with other Quaternary shoreline successions of this type, the establishment of chronological sequence and absolute age of individual strandlines is fraught with difficulties. Palaeomagnetic studies of cores from recent stratigraphic drilling suggests that the oldest component of the complex Naracoorte Range barrier, shown in Figure 1, is older than the Bruhnes-Matuyama magnetic reversal at 720 000 years; all ridges to the southwest are younger (Cook *et al.* 1977). Limited radiocarbon dating of the youngest deposits in the sequence reported by Blackburn (1966), von der Borch (1976), Cook *et al.* (1977) and Schwebel (1979)[1] has established a preliminary chronology of Holocene and late Pleistocene sediments from lagoonal and lacustrine areas near the present coast. Uranium-series dating techniques have been applied to aragonitic lagoonal sediments and molluscs dating back to the last interglacial high sealevel (Schwebel 1979)[1].

This paper reports an initial application of the amino-acid racemization (AAR) dating technique (Masters & Bada 1978) to the problem of deciphering the chronology of some aspects of the Woakwine strandline region shown in Figure 1. It serves as an independent check on uranium series dates obtained from

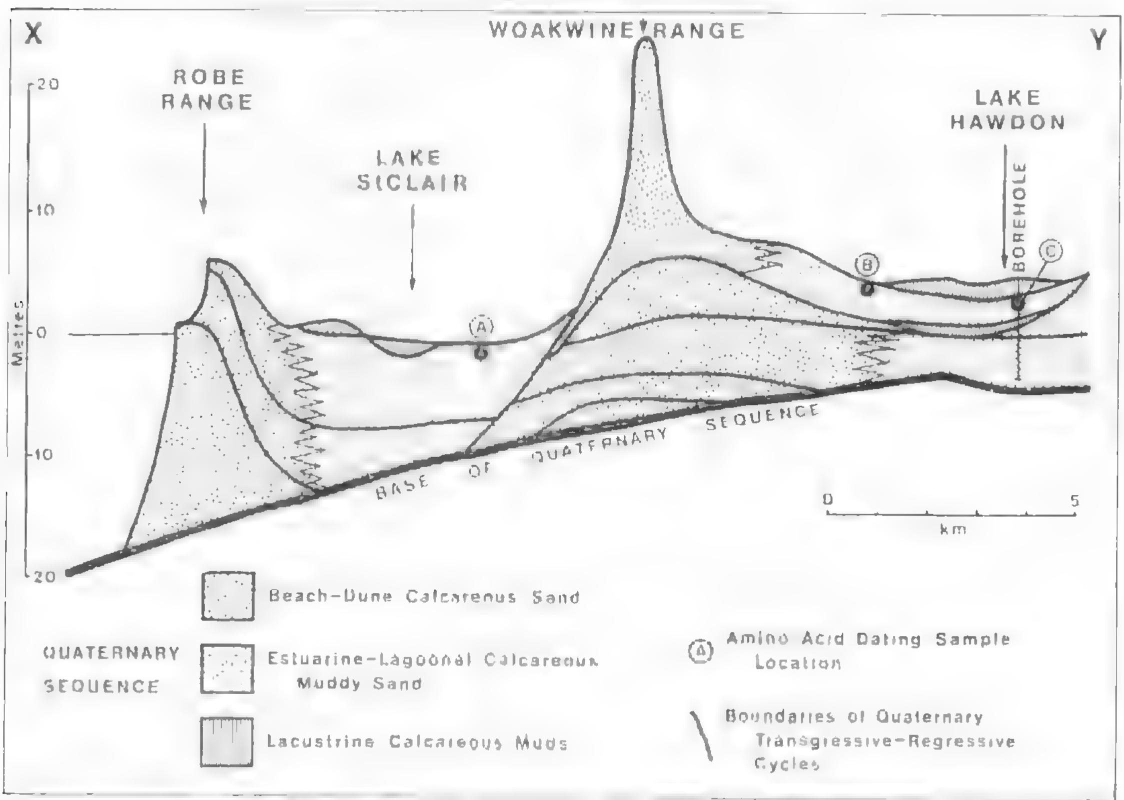

Fig. 2. Section X-Y (Fig. 1), after Schwebel[1] showing Flinders University stratigraphic borehole and locations of samples A, B and C.

samples beyond the range of ^{14}C techniques (Schwebel 1979)[1].

Sample localities

Material used for AAR dating was obtained from localities A, B and C (Fig. 2) on the transect X-Y (Fig. 1). The mollusc *Katelysia scalarina* (Lamarck) was selected as the species most suitable for the racemization analysis since it has relatively thick, non-porous valves.

Sample A is a surface sample from a shallow pit at Lake St Clair where articulated specimens were selected. This locality lies on the first interdune flat inland from the present coast, where dates on molluscs have been reported by Blackburn (1966) at 4330 ± 100 years using ^{14}C. Stratigraphic observations by Schwebel (1979) are in accord with the above date, and show the sediments to have been deposited during the peak of the Holocene sealevel transgression prior to final separation of the flat from the ocean by modern barrier accretion and possible sea level decline. Because of the established radiocarbon dates, this sample was used as a reference point for the calculations involved in determining the ages of samples B and C.

Sample B is from the side of a drain locally known as Drain L which intersects the Woakwine Range barrier and its related estuarine-lagoonal strata to the east. Shells comprising sample B, many of which are in-situ, occur within a 20–30 cm thick indurated layer, on an erosion surface which is onlapped by Holocene lacustrine calcareous muds of the most recent Lake Hawdon phase.

Sample C, interpreted by Schwebel (1979)[1] to come from the same horizon as that of sample B, was collected from a stratigraphic borehole (Fig. 2) from a mollusc-rich layer 280 cm below the sediment surface. Articulated samples of *Katelysia scalarina* (Lamarck) were sampled and used for dating.

Dating methods and procedures

Approximately 5–10 grams of a single cleaned *Katelysia* valve were processed according to the procedures described for the "total" fraction by Masters & Bada (1977). The alloisoleucine/isoleucine (alleu/iso) ratio was determined on a *Beckman-Spinco* Model 118 automatic amino acid analyzer. The enantiomeric ratios of the other amino acids were determined by gas chromatography of the N-trifluoroacetyl-L-prolyl peptide methyl esters (Hoopes *et al.* 1978).

[1] Schwebel, D.A. (1979) Quaternary stratigraphy of the southeast of South Australia. Ph.D. thesis (unpubl.). Flinders Univ. of S. Aust.

TABLE 1. *Extent of amino acid racemization in Katelysia shells from marine terrace deposits in southern Australia*

Sample	D/L alanine	D/L glutamic acid	D/L leucine	alleu/iso
A	0.29	0.17	0.28	0.11
B	0.63	0.30	0.35	0.28
C	0.73	0.37	0.46	0.36
Modern *Katelysia*	0.13	0.08	0.09	0.01

Results and discussion

The racemization results for the various samples are given in Table 1. The extent of AAR in sample A is consistent with a Holocene age for this sample. Substituting the measured alleu/iso ratio and an age of 4330 years (Blackburn 1966) in eq. (2) of Masters & Bada (1977) yields $k_{iso} = 2.3 \times 10^{-6}$ yr^{-1}. The value of K_{eq} in this equation was assumed to be ~1.3. This k_{iso} value is in close agreement with that calculated using Holocene *Chione* molluscs from Southern California coastal archaeological sites. This is the expected result due to the similarity of the mean annual air temperatures of the Californian and South Australian localities (Felton 1965; Floegel 1972), and since the *Katelysia* and *Chione* species have similar shell morphologies.

The extent of AAR in sample C is nearly identical to that measured in *Chione* (Masters & Bada 1977) and *Protothaca* molluscs (Wehmiller 1977) from a terrace deposit in San Diego, California. This terrace has been dated at 120 000 ± 10 000 years by uranium-series dating of corals (Ku & Kern 1974). Since the Holocene sample suggests that the rate of racemization is similar at the Californian and Australian sites, the similarity of the extent of racemization in sample C and the 120 000-year-old Californian terrace supports the conclusion that sample C corresponds in age to the maximum high-sea level stand during the last interglacial period (i.e. Stage 5e in the O^{18}/O^{16} palaeotemperature curve, ~125 000 B.P.).

In comparison to sample C, the extent of AAR is consistently slightly less in sample B. On this basis, it would appear that sample B may come from one of the other episodes of

high sea level, tentatively dated at ~85 000 and 105 000 years B.P., which occurred in the vicinity of the last interglacial period (Bloom *et al.* 1974). Substituting the measured alleu/iso ratio for sample C and an age of 120 000 years for this sample into eq. (2) in Masters & Bada (1977), yields $K_{iso} = 2.9 \times 10^{-6} yr^{-1}$. Using this k_{iso} value to date sample B yields an age of ~92 000 years.

The AAR dates for samples B and C given above imply that the uppermost portion of the Woakwine Range strandline complex was formed during the last interglacial high sea level. This is in accord with the uranium series data of Schwebel (1979).

Sample B with an age of 92 000 years appears slightly younger than C, which is about 120 000 years old. In fact, the age of B lies approximately midway between the 85 000 and 105 000-year-old sealevel highs described by Bloom *et al.* (1974). If the assumption is made that C actually correlates with the 125 000 year sealevel high (i.e. that the date used to calculate the k_{iso} value given above is a few thousand years too young), then B could possibly be correlated with the established 105 000-year-old sealevel high. On the other hand the small number of samples, and the resolution of the amino acid dating technique as applied to the study area, may imply only that the two samples B and C were laid down in response to some stage or stages of the last interglacial sealevel maxima, of the order of 120 000 years ago.

Acknowledgments

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NEW CRETACEOUS AND TERTIARY CRABS (CRUSTACEA: BRACHYURA) FROM AUSTRALIA AND NEW ZEALAND

BY S. BARKER

Summary

From the Cretaceous of Australia and New Zealand three new genera of Brachyura, one new subgenus, and seven new species are described and one new family is proposed. Four new species from the Eocene are described, one from Australia and three from New Zealand, and changes in taxonomy and nomenclature are made. The new classification of the Brachyura (Guinot 1977) is applicable to the new material which contributes significantly to the clarification of taxonomic and phylogenetic relations at an early, critical stage in the evolution of the Brachyura. Modified Tethyan palaeobiogeographic relations of the Cretaceous and Palaeogene faunas are recognised.

NEW CRETACEOUS AND TERTIARY CRABS (CRUSTACEA: BRACHYURA) FROM AUSTRALIA AND NEW ZEALAND

by M. F. GLAESSNER*

Summary

GLAESSNER, M. F. (1980) New Cretaceous and Tertiary crabs (Crustacea, Brachyura) from Australia and New Zealand, *Trans. R. Soc. S. Aust.* **104**(6), 171-192, 28 November, 1980.

From the Cretaceous of Australia and New Zealand three new genera of Brachyura, one new subgenus, and seven new species are described and one new family is proposed. Four new species from the Eocene are described, one from Australia and three from New Zealand, and changes in taxonomy and nomenclature are made. The new classification of the Brachyura (Guinot 1977) is applicable to the new material which contributes significantly to the clarification of taxonomic and phylogenetic relations at an early, critical stage in the evolution of the Brachyura. Modified Tethyan palaeobiogeographic relations of the Cretaceous and Palaeogene faunas are recognised.

Classification

A new classification of the Decapoda Brachyura proposed by Guinot (1977, 1978) is of particular interest to students of the evolution of these crustaceans. Based on generally sound and stated principles, and on a re-examination of a very large amount of zoological material as well as literature, it takes into consideration conclusions reached by palaeontologists, questioning some of these conclusions specifically. New material from Australia and New Zealand provides a suitable starting point for the task of answering some of the queries raised, and of testing the suitability of the proposed new system of the Decapoda Brachyura. The following tabulation places the new finds in the framework of Guinot's classification and indicates their age and occurrence.

Section Podotremata Guinot, 1977

Subsection Dromiacea de Haan, 1833

Superfamily Homolodromioidea Alcock, 1899

Family Prosopidae von Meyer, 1860

Oonoton woodsi nov. gen., nov. sp. Upper Albian, central Queensland and South Australia.

Subsection Archaeobrachyura Guinot, 1977

Superfamily Homoloidea White, 1847

Family Homolidae White, 1847

Homolopsis etheridgei (H. Woodward, 1892). Upper Albian, central Queensland.

Homolopsis spinulosa nov. sp. Upper Cenomanian, northern Australia.

Superfamily Raninoidea de Haan, 1833

Family Raninidae de Haan, 1833

Notopocorystes (Cretacoranina) exiguus nov. sp. Lower Cenomanian, Northern Australia.

Hemioon novozelandicum nov. sp. Upper Albian, New Zealand.

Ranilia pororariensis nov. sp. Upper Eocene, New Zealand.

Lyreidus waitakiensis nov. sp. Middle to Upper Eocene, New Zealand.

Superfamily Tymoloidea Alcock, 1896.

Family Torynommidae nov. fam.

Torynomma (Torynomma) flemingi nov. sp. Upper Senonian, New Zealand.

Torynomma (Paratorynomma) dentatum nov. subgen., nov. sp. Upper Cenomanian—Lower Turonian, northern Australia.

Dioratiopus salebrosus Woods, 1953 Upper Albian, Queensland and South Australia.

Dioratiopus sp. Upper Cenomanian, northern Australia.

?*Eodorippe spedeni* nov. gen., nov. sp. Upper Senonian, New Zealand.

Section Heterotremata Guinot, 1977.

Superfamily Portunoidae Rafinesque, 1815

Family Portunidae Dana, 1852.

Subfamily Psammocarcininae Beurlen, 1930.

Rhachiosoma granulifera (Glaessner, 1960) Upper Eocene, New Zealand.

Family uncertain.

Pororaria eocenica nov. gen., nov. sp. Upper Eocene, New Zealand.

Superfamily Xanthoidea McLeay, 1838.

Family Panopeidae Ortmann, 1893.

Panopeus whittenensis nov. sp. Upper Eocene, South Australia.

The most distinctive innovation affecting the classification of the Brachyura discussed here

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is the demotion of the "Section Dromiacea" which has dominated considerations on the origin and evolution of the Mesozoic Brachyura for more than a century. Guinot recognises three sections: the Podotremata, Heterotremata and Thoracotremata, named according to the position of the gonopores. This looks rather like a single-character classification to which I objected (Glaessner 1969) when the peditreme-sternitreme distinction (Bouvier 1897) was used by Gordon (1963) to remove the former group from the Brachyura. However, Guinot (1978) has amply demonstrated that it is a distinction by grades, the use of which she finds inevitable for taxa of high rank while following to some extent "pré-occupations d'ordre cladistique" for lower-rank taxa. This taxonomic innovation involves recognition of two subsections of the Podotremata, the Dromiacea and the Archaeobrachyura. The former comprise the Superfamilies Homolodromioidea and Dromioidea, the latter the Homoloidea, Raninoidea and Tymoloidea. This classification is significant for the present investigation. There is ample morphological evidence for close links between the Tymoloidea and the Homoloidea. The Dromioidea (Families Dromiidae and Dynomenidae) have taken a different evolutionary path. With reference to the descriptions and discussions which follow, it is sufficient to note here that *Homolopsis* and *Torynomma* (with related genera) are morphologically close and, as Wright & Collins (1972) have indicated, appear to have had Prosopidae, hence Homolodromioidea, as ancestors in Jurassic time. The Dromioidea differ significantly from this group in many morphological, embryological and ethological characters. For the question of the evolution and systematic position of the Raninoidea there is no significant new material under discussion here (see Förster 1968, Števčić 1973). I had previously (Glaessner 1969) assigned the Tymolinae to the Dorippidae, following the latest comprehensive classification available at that time (Balss 1957). This is now unnecessary and unacceptable, since Guinot's work has shown that the oxystomatous condition (which has to do with the direction of the inhalent and exhalent currents of water under the carapace) was reached independently by very different groups of crabs. Thus there is no justification for retaining the artificial taxon Oxystomata. With this demonstration most of the major classification of the Brachyura, of long standing but often questioned, had to be abandoned. The origin of all or some of the older Heterotremata (Dorippoidea, Calappoidea, Corystoidea (=Cancriformia), Portunoidea and (questionably) Xanthoidea (see Wright & Collins 1972) from Cretaceous Tymoloidea or their ancestors is possible or even probable, but these investigations would lead beyond the limits set by the material here described.

Summary of stratigraphic distribution

(New Zealand species marked with asterisk)

Upper Albian: *Oonoton woodsi, Homolopsis etheridgei, *Hemioon novozelandicum, Dioratiopus salebrosus.*

Lower Cenomanian: *Notopocorystes (Cretacoranina) exiguus.*

Upper Cenomanian: *Homolopsis spinulosa, D.* sp.

Upper Cenomanian to Lower Turonian: *Torynomma (Paratorynomma) dentatum.*

Campanian-Maastrichtian: **Torynomma (T.) flemingi, *Eodorippe spedeni.*

Middle to Upper Eocene: **Lyreidus waitakiensis.*

Upper Eocene: **Ranilia pororariensis, *Rhachiosoma granulifera, *Pororaria eocenia, Panopeus whittenensis.*

Remarks on palaeobiogeography

While we know only a small sample of the Brachyura of the Cretaceous and Eocene of Australia and New Zealand, theoretical conclusions are unwarranted. It is worth noting that known relations are dominantly with European genera. *Homolopsis, Notopocorystes* (which is almost cosmopolitan), *Hemioon, Dioratiopus, Rhachiosoma* and *Panopeus* (which is also Atlantic) are well known from Europe. As far as the Australasian region is concerned, the origin of these genera can be considered as Tethyan. *Torynomma* has its range extended from Queensland to the north of Australia in the Cenomanian, and to New Zealand in the Campanian-Maastrichtian. Its close relative *Dioratiopus*, a genus shown to include many European species, is recorded, in addition to Queensland, from northern South Australia and from Melville Island north of Darwin. The undescribed macruran and thalassinacean decapods from the Cenomanian of the island (*Paraclytia, Hoploparia, Trachysoma* and *Protocallianassa*) are well known from the European Upper Cretaceous. The Tethyan

relations of the Brachyura from Bathurst Island are in agreement with the character of its Cenomanian ammonite fauna (Wright 1963). *Eodorippe* from the Upper Senonian of New Zealand is endemic, and the endemic Recent *Nectocarcinus* may have had an ancestor dating back to the Eocene in the same region, the new genus *Pororaria*.

Descriptions

Family Prosopidae

Oonoton nov. gen.

Derivation of name: From Greek oon: egg, noton: back, with reference to shape.

Diagnosis: Carapace ovoid, without sharp lateral margins, posterior margin short, rostrum triangular, truncated, with transverse groove and row of granules at base; eye sockets close-set with strong supra- and infraorbital spines; mesogastric lobe long and narrow, urogastric lobe indistinct, carapace surface granulated.

I had intended to assign this fossil to *Vectis* Withers, 1946, but Mr C. W. Wright kindly informed me in July 1980 of his disagreement with such an extension of this taxon. I accept his view that the differences between the Australian crab and the three English species are of generic significance. They leave *Oonoton* closer to *Vectis* than to other genera.

Oonoton woodsi nov. sp.

Derivation of name: After Dr J. T. Woods, Director of Mines, Queensland who has made valuable contributions to the knowledge of Cretaceous Decapoda from Queensland.

Material: 1. Holotype—An almost complete carapace, Qld Mus. F 2876. 2. One fragmentary carapace, Geological Survey of South Australia No. Cr 1.

Localities: 1. Currane Station, 16 km N of Dartmouth, central Queensland. 2. 14 km W of Mt Dutton (Loc. 17, Map Sheet 5/571, see Bull 40, Geol. Survey S. Aust. p. 44).

Preservation: The Queensland specimen is well preserved in a smooth, round, concretionary nodule, similar to those which contain other crabs from the Queensland Cretaceous. The South Australian specimen consists of internal moulds of two angular fragments of the posterior portion of the carapace, partly overlapping, in a concretion containing numerous mollusca. The mode of preservation and the association suggest that the carapace may have been broken by a predator, probably a belemnite or an ammonite.

Age: Upper Albian, Tambo Formation of Queensland and Oodnadatta Formation of South Australia.

Description: Carapace of holotype ovoid, 27 mm long, 22.4 mm wide, about 8.5 mm high. Convex antero- and posterolateral margins of about equal length; lateral margins almost parallel. longitudinal and transverse profiles of carapace (Figs. 1A, B) strongly and smoothly convex. Apically truncated triangular rostral plate directed forward, set off from anterior slope of carapace by transverse groove and row of granules in front of mesogastric region. Eye sockets deep and small, with strong, conical, supraorbital and long infraorbital spines which are twice as long and set below. Anterolateral outlines diverge to crossing points of cervical grooves and widen only slightly to metabranchial regions. Posterior margin apparently not as long as in *Vectis*. Regions well marked by smooth, shallow furrows. Mesogastric lobe not subdivided. Almost entire surface of carapace fairly evenly covered with large granules. Additional small tubercles on metabranchial regions, and 5 distinctive, larger, granulate elevations. Two are symmetrically arranged on mesogastric lobe, 2 on metragastric lobe which is divided by deep median furrow, 1 on cardiac lobe. Its distance from posterior margin ½ that from base of rostrum. Cardiac grades into narrow intestinal lobe.

This species differs from two Aptian and one Albian species of *Vectis* previously described from England in details of shape and surface sculpture. It has all the significant characters of their carapace regions but they are not as tumid and therefore less conspicuous in the new species. The characters which are preserved in the smaller specimen from South Australia do not differ from those of the holotype from Queensland.

Family Homolidae

Homolopsis Bell, 1863

Homolopsis etheridgei (Woodward, 1892)

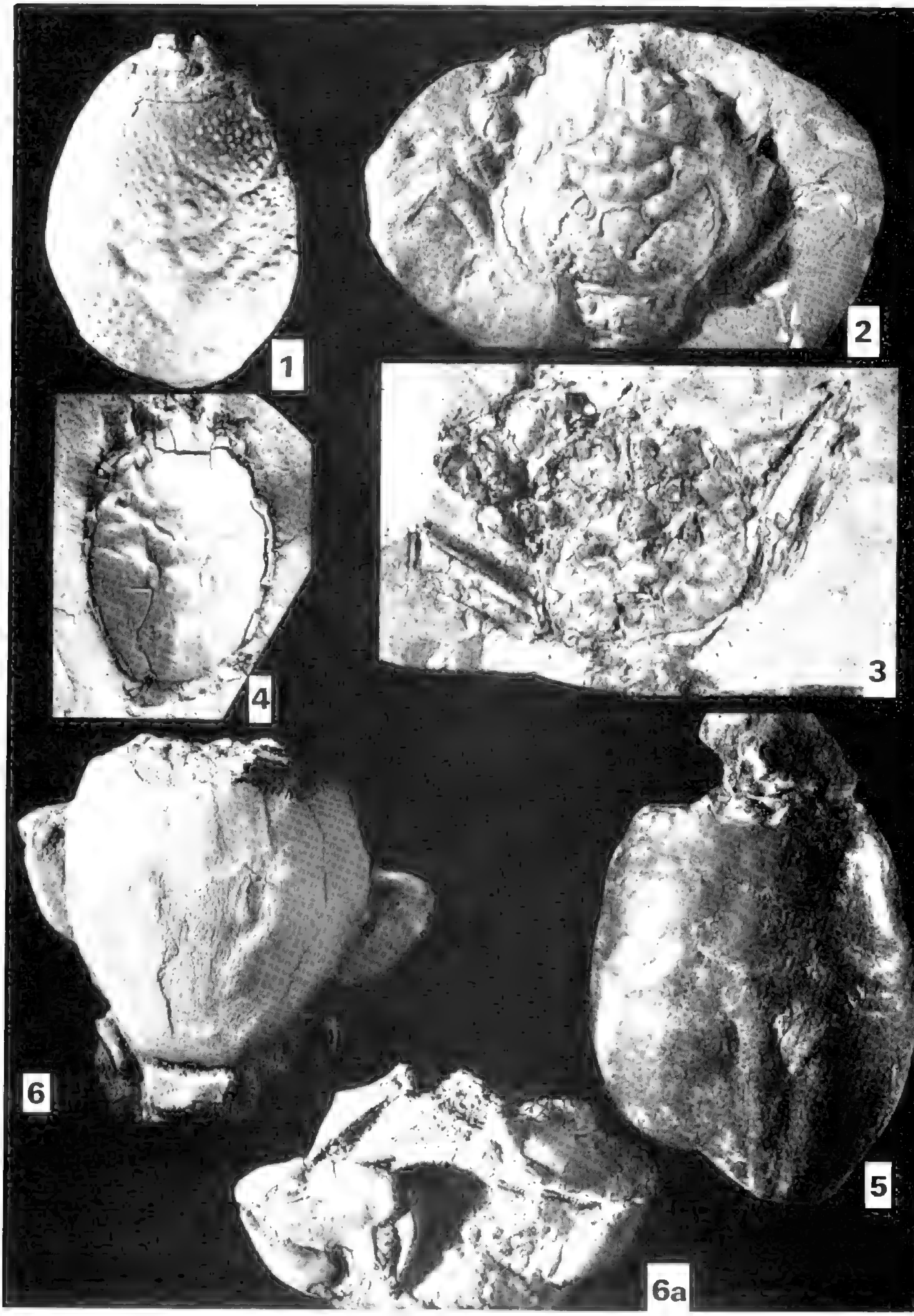
FIG. 2

Prosopon etheridgei Woodward 1892, p. 301, pl. 4; Etheridge 1917, p. 5, pl. 1, fig. 1–4.

Homolopsis etheridgei: Van Straelen, 1928, p. 619; Woods, 1953, p. 50, pl. 2, fig. 1–3, text fig. 1.

Material: One almost complete specimen (F22945).

Locality: "Currane", 14 km N of Dartmouth, central Queensland. Coll. J. T. Woods 1955.


1
2
3
4
5
6
6a

Age: Upper Albian, Tambo Formation.

Remarks: This specimen is figured here for comparison for completeness of the record of currently known Australian Cretaceous crabs. It has a significantly more convex carapace than the species figured by Wright & Collins (1972) and its upper surface is certainly not "more or less flat" as their generic diagnosis of *Homolopsis* requires. It may be appropriate to place the Australian species in a new subgenus unless species with traditional shape characters exist.

Homolopsis spinulosa nov. sp.
FIG. 3, 3A

Holotype material: One small, somewhat crushed specimen with counterpart, P22934. Coll. B. Daily 1954

Locality: South coast of Melville Island, N.T., about 10 km NW of Cape Gambier.

Age: Upper Cenomanian, Bathurst Island Formation, about 8 m above "Tapara Bed"

Preservation: Preserved in a slightly weathered yellowish clay is the cephalothorax with two abdominal somites, the left cheliped and parts of all other pereiopods. Ferruginised and affected by compaction and weathering; most of the carapace margins defective. Artificial moulds of the counterpart show details not recognisable in the damaged specimen.

Description: Carapace about 12 mm long and 14 mm wide, fronto-orbital width about 8 mm; anterolateral margins diverging, posterolateral margins slightly converging; posterior margin about 5 mm long, curved, with granulated edge. Ornamentation consists of distinct, granulated tubercles; at least 1 epigastric, 2 protogastric, 1 hepatic, 2 epibranchial and 3 metabranchial tubercles present on each side and also metagastric and cardiac tubercle-bearing ridges. Surface finely and evenly granulated. Left cheliped short and robust, with a spinose carpus; P2 and P3 strong, long, with spinose edges, the P4 appear near the posterolateral angles of the carapace, thin, smooth P5 near the base of the abdomen. First two abdominal somites about 5 mm wide, rectangular in outline, subequal, about 0.75 mm long, with two longitudinal shallow grooves and elevations on a blunt transverse ridge on each somite. Abdomen extending horizontally backward.

This species appears to differ from other species of *Homolopsis* and also from "*Glaessneria*" *depressa* (Carter) as described by Wright & Collins (1972) mainly in details of ornamentation. The *linea homolica* is partly visible and partly obscured by compression and fracturing of the only known carapace.

Family Raninidae
Notopocorystes M'Coy, 1849

Notopocorystes (Cretacoranina) exiguus nov. sp.
FIG. 4, 4A

Derivation of name: From Latin exiguus: small.

Material: One carapace, with counterpart, in a bore core. Forwarded by Mr P. Bollen. P22929.

Locality: Bathurst Island Oil Development Well No. 2, about 4 km N of the mouth of Pipanyamili Creek, about 30 km W of Bathurst Island Mission. Core from 280 m depth.

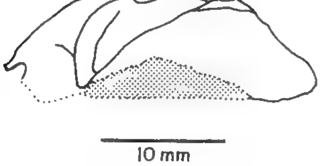
Age: Lower Cenomanian, Bathurst Island Formation, grey clay.

Preservation: Carapace undistorted but most of the extremely fragile shell attached to the counterpart and anterolateral and orbital margins damaged.

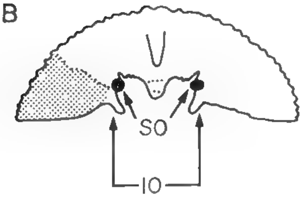
Description: Carapace ovoid, 15 mm long, 10 mm wide. Width of the fronto-orbital margin about 5.4 mm. Carapace gently convex transversely and longitudinally, greatest height in the centre. Median ridge very faint. Rostrum bifid, medially grooved, slightly deflexed. Two supraorbital fissures. Extraorbital teeth could not have been large. Only 3 very weak lateral tubercles, 1 hepatic, 1 epibranchial and 1 extremely weak mesobranchial, followed by a finely granulated ridge along posterolateral margin. Posterior margin about 6 mm long but not well preserved. Cervical furrow, gently curved, runs from a notch in front of the epibranchial tubercle in a forwardly convex curve, then follows a sinuous course to distinct posterior gastric pits. Epibranchial furrows short.

Fig. 1. *Ooniton woodsi* nov. sp. x2.
Fig. 2. *Homolopsis etheridgei* (H. Woodward).
Fig. 3. *Homolopsis spinulosus* nov. sp. x3.
Fig. 4. *Notopocorystes (Cretacoranina) exiguus* nov. sp. x3.
Fig. 5. *Heminon novozelandicum* nov. sp. x3.
Fig. 6. 6a. *Raulila pororariensis* nov. sp. x2. a—dorsal view, b—ventral view

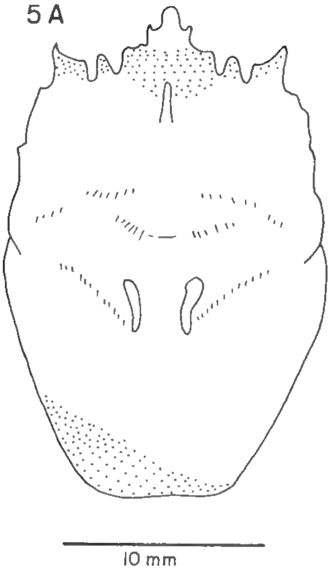
1A



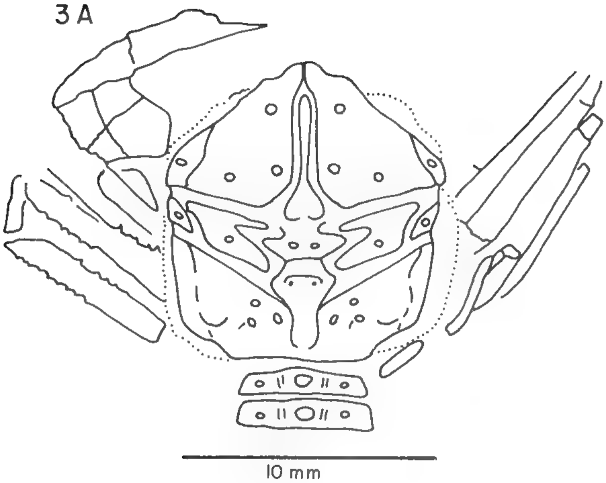
1B



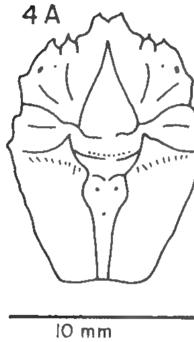
5A



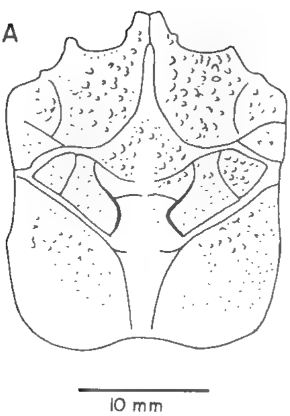
3A



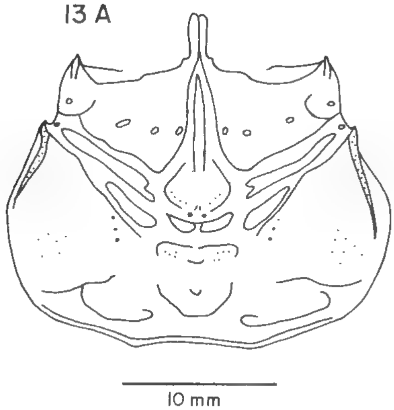
4A



12 A



13 A



transverse, do not reach the cervical groove. Branchiocardiac furrows more distinct, particularly their posterior edges, merging with the deep epimeral grooves. Epimeral and posterior gastric muscle attachments well marked on the inside of the carapace. The described furrows, together with hepatic and weaker mesogastric furrows form a peculiar radiating pattern on the outer surface which is finely pitted and granulated. Two elongate, tuberculate protuberances on the anterolateral parts of the carapace: outer ones smaller and prominent on the hepatic lobes, inner ones situated on outer portions of the protogastric lobes which are partly separated from the main parts by shallow grooves.

Remarks: The weak marginal spines and the surface sculpture place this species in the subgenus *Cretacoranina* Mertin, 1941. It does not appear to be particularly close to any of its known species but detailed comparison must await the discovery of further specimens.

Hemioon Bell, 1863

Hemioon novozelandicum nov. sp.

FIG. 5, 5A

Holotype material. One specimen in a hard concretion. Geological Survey of New Zealand GS11845.

Locality: Swale Stream, Coverham, South Island of New Zealand (P30/f 56).

Age: Latest Albian. Lower part of Swale Siltstone, Ngaterian local Stage. Dr I. Speden (in litt. 1977) suggests Lower Ngaterian, from near the base of the *Worthoceras parvum* Assemblage Zone of Henderson (1973).

Preservation: Cephalothorax preserved as an internal mould, off central position, in a very hard concretion which does not split evenly. Sternum not visible but fragments of legs and chelae preserved in slightly displaced positions and much of the inside of the carapace shell is visible. Although the rostrum remained in the counterpart matrix when the concretion was split, it was possible to extract its tip and rejoin it so that the length of the rostrum could be determined (Fig. 5A).

Description: Cephalothorax ovoid, flattened longitudinally and convex transversely, lateral margin discontinuous, weakly developed. Two weak anterolateral spines and an acicular extraorbital spine with granulated surface. Orbits large, well marked, with two supraorbital fissures and a stout supraorbital tooth. Rostrum about 3 mm long, straight, with two lateral basal spines. Markings on carapace surface very weak. Internal mould shows median parts of cervical groove curving laterally from posterior gastric pits, the anterior tip of the mesogastric lobe, epimeral grooves, and relics of the branchiocardiac grooves. Narrow median ridge marking cardiac and intestinal lobes. Strong muscle pits in the hepatic regions. Surface of carapace finely pitted where it can be seen. Posterolateral margins granulate. The greatest width (16.5 mm) is found between posterolateral margins which are separated from the anterolateral margins by a slight constriction behind the second anterolateral teeth. Marked, narrow, pterygostomial ridge and a wide depression along brachiostegite. Posterior margin missing. Carapace was at least 25 mm long, greatest width is at about 0.6 of its length.

Remarks: The new species differs from *H. elongatum* (A. Milne Edwards 1862) in the shape of the carapace, the weak lateral teeth and the absence of surface tubercles. *H. circumvlator* Wright and Collins 1972 also has strong anterolateral spines and convergent lateral margins on the posterior half of the carapace. These differences remove the new species further from *Raninella* as revised by Wright & Collins than those considered by these authors. It differs more in shape and carapace sculpture from *Notopocorystes* (*Cretacoranina*).

Ranilia H. Milne Edwards, 1837

Ranilia pororariensis nov. sp.

FIG. 6, 6a

Holotype material: One carapace, slightly distorted by flattening, most of fronto-orbital margin missing. Chelipeds and some displaced or broken pereiopods preserved, sternum not

Fig. 1A. *Ommaton woodsi* nov. sp., left side view. 1B front view. SO—position of supraorbital spine, IO—infraorbital spine. Stippled parts of carapace are missing or concealed.
Fig. 3A. *Homolopsis spinulosus* nov. sp. Partial reconstruction. Dotted line indicates outline of crushed carapace.
Fig. 4A. *Notopocorystes* (*Cretacoranina*) *ovalis* nov. sp. Reconstruction of carapace showing pattern as seen on inner surface.
Fig. 5A. *Hemioon novozelandicum* nov. sp. Reconstruction of carapace. Stippled parts are missing.
Fig. 12A. *Dioratiopus salebrosus* Woods. Reconstruction of carapace.
Fig. 13A. *Eodorippe spedeni* nov. sp. Diagrammatic reconstruction of carapace pattern and rostrum.

visible, first abdominal somite preserved. Canterbury Museum, Christchurch, New Zealand, No.zfc 7. Coll. R. S. Allen, Feb. 1935.

Locality: Coastal cliffs at Pororari, 2.4 km N of Punakaiki. Sheet No. S37/723. Grid ref. C852318.

Age: Kaiatan—Runangan, Late Eocene.

Description: Carapace ovoid, strongly convex transversely; height about equal to half the width; gently convex longitudinally Distance between the extraorbital and lateral acicular teeth equals that between lateral teeth and point of greatest width which is at the level of the posterogastric pits; distance from this point to posterior margin almost 3 times longer. Posteriorly convergent posterolateral margins marked by a smooth ridge which is convex in dorsal view for first half of their length, then straight. Posterior margin straight. A very faint median ridge on posterior half of carapace. Two supraorbital fissures separated by a small tooth, only base preserved. Surface of carapace uniformly pitted, marked only by weak epimeral muscle impressions. First abdominal segment trapezoidal, surface pitted but otherwise smooth. Propodus of cheliped has sharp, denticulated upper edge and strongly deflexed fixed finger. Dactylus gently curved, with narrow dorsal groove between two ridges.

Remarks: The new species differs in shape and ornamentation and in the deflexed fixed finger from living species. It is distinguished by the weak longitudinal ridge and the anterolateral teeth from the Eocene *R.* ("*Notopella*") *vareolata* (Lörenthey). Further specimens in a better state of preservation and preparation are required for complete description and comparison.

Lyreidus de Haan, 1841

Lyreidus waitakiensis nov. sp.

FIG. 7, 7a

Holotype material: One carapace, front mostly missing. Canterbury Museum, Christchurch, New Zealand, No. zfc 30.

Locality: Black Point, Waitaki Valley. S127/368, Grid reference c 364 916. Another less well preserved specimen (Canterbury Museum, No. zfc 8, coll. R. S. Allen Feb. 1935, from coastal cliffs at Pororari, 2.4 km N of Punakaiki) probably belongs to this species.

Age: Middle to Upper Eocene, Tapui glauconitic sandstone, Bortonian Stage. This may be the oldest known species of *Lyreidus*. The other specimen, tentatively named *L.* cf. *waitakiensis*, is from the Upper Eocene, Kaiatan-Runangan.

Preservation: Inner layer and parts of outer of shell of holotype present. Complete branchiostegites, part of the left antennal base and small, displaced sternal fragments also preserved.

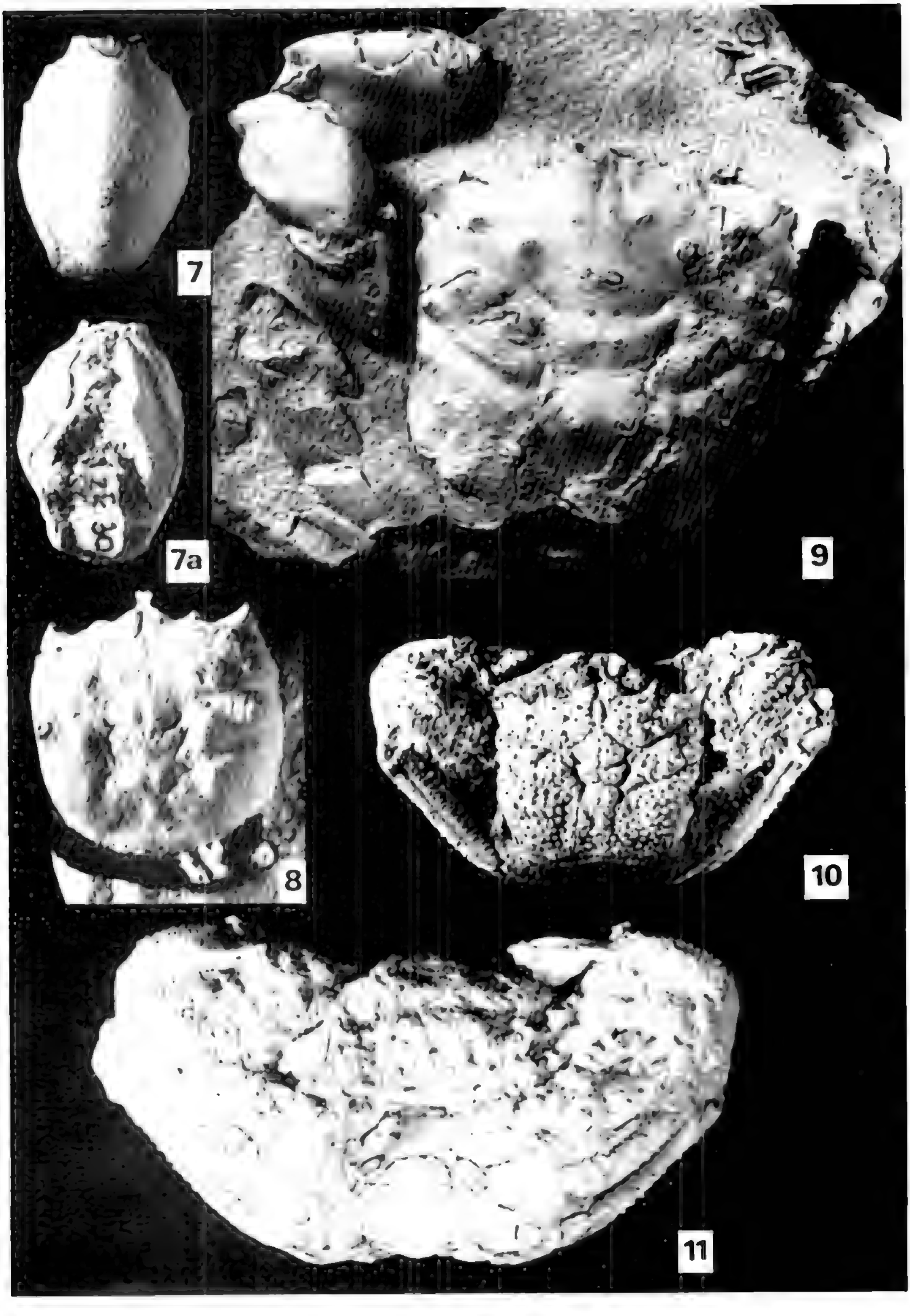
Description: Carapace ovate; fronto-orbital region 6.5 mm wide, with 2 supraorbital fissures; anterolateral margins diverging from the extraorbital to obliquely pointed lateral teeth. Distance between their tips is about 3.5 mm, equal to greatest width of carapace measured about 3 mm behind them. Anterolateral margins rounded, a bluntly conical tooth on each side halfway between extraorbital and lateral teeth. A blunt edge extends a short distance behind the lateral teeth, replaced from below by a distinct, sharp, posterolateral ridge with small granules. Posterolateral margins converge to arcuate posterior margin which equals fronto-orbital margin in length. Carapace strongly convex transversely, gently convex longitudinally; pterygostomial regions inflated. Pleural suture sinuous anteriorly, parallel to lateral margins and a short distance below them. Surface of carapace shows posterogastric pits 2 mm behind level of the lateral teeth, and weak epimeral attractor muscle markings some distance behind them; smooth but may have been faintly pitted and weakly granulated in some places. Two weak epigastric tubercles. Pterygostomial regions granulated. Orbits only slightly oblique in frontal view, with small infraorbital spines separated by fissures from extraorbital teeth Antennal base has lateral, longitudinal, granulated ridge with channel along its outer side, between it and edge of carapace; it may lead to the proximal side of the infraorbital tooth.

Remarks: This species can be distinguished by its ovoid shape and its ornamentation. The

Fig. 7, 7a. *Lyreidus waitakiensis* nov. sp. x2. a—dorsal view, b—ventral view.

Fig. 8. *Torynomma quadratum* Woods. Plaster cast of holotype x2. Rostrum drawn from another specimen.

Figs. 10, 11. *Torynomma (Paratorynomma) dentatum* nov. sp. 10—holotype, x1.5, dorsal view. 11—paratype F 22931, x2. Ventral view with anterior sternum and abdomen of ♀ and pereiopods.


7
7a
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9
10
11

shape of the carapace appears to be of slightly more generalised raninid type than in the Miocene and living species which are anteriorly more sharply narrowed and strongly elongated.

Family Torynommidae nov. fam.

The genus *Torynomma* was originally placed in the family "Prosoponidae" (*recte* Prosopidae), together with *Dioratiopus* (Woods 1953, p. 52). These genera have hardly more than a few primitive (plesiomorphic) characters in common with the Prosopidae but they do not have any of the distinctive, diverse developments of shape of the carapace and rostrum or the dominance of the transverse carapace grooves which characterise this family. The placing of *Torynomma*, *Dioratiopus* and other extinct genera in the subfamily Tymolinae Alcock, 1896, as proposed by Glaessner (1969) is considered inappropriate by Wright & Collins (1972). Concerning the placing of the Tymolinae in the Dorippidae, Gordon (1963, p.56) stated: "Certainly the so-called Tymolinae with sternal furrows and coxal genital pores should not be placed in the same family as the dorippids without sternal furrows and with the genital openings of the female sternal". I rejected (Glaessner 1969, p.R440) Gordon's further conclusion that it seems logical to exclude all peditreme crabs "from the Brachyura, restricting the term to the vast majority of crabs with the female genital openings sternal". I noted that the Dromiacea, Raninidae and Tymolinea which have coxal female gonopores are "exceptional" and that their separation "on the basis of an obviously primitive character is an extreme application of 'horizontal classification' which is not acceptable, particularly as the steps in the evolution from the primitive peditreme to the advanced sternitreme condition have not yet been studied on fossil material". Hence I followed the earlier systematists and Balss (1957) who placed the Tymolinae in the family Dorippidae. Guinot's work (1977, 1978) has now removed the traditional major subdivisions of the Brachyura such as the Oxystomata, which had been hampering the development of systematics in this group since the middle of the last century. It showed that Gordon had been remarkably far-sighted in recognising the peditreme-sternitreme evolutionary transition as a fundamental change which can provide a firmer basis for the major classification of the Brachyura than the diagnostic characters of the traditional major taxa. However, this reclassification also rejected Gordon's "logical conclusion" that the peditreme crabs are not Brachyura. The steps in the evolution from the peditreme to the sternitreme grade (Guinot's Sections Podotremata and Heterotremata) are now better documented both in living and in fossil forms including those described or reconsidered here. Earlier erroneous classifications on family and subfamily level (Balss, Glaessner) must now be corrected in the light of these data. However, they are still incomplete as far as palaeontological material is concerned.

Wright & Collins (1972) assigned to the family Cymonomidae (erroneously ascribed to Ihle 1916 but actually named by Bouvier 1897 as Cymonomae) the fossil genera *Glaessneria* Wright & Collins, 1972 (re-named *Glaessnerella* in 1975) and *Dioratiopus* J. T. Woods, 1953, considering them as "closely allied". It will be shown below that they are synonymous. Also included was *Mithracites* Gould, 1859, but *Withersella* Wright & Collins, 1972 and *Binkhorstia* Noetling, 1881 were omitted and rather unconvincingly placed in the Carcineretidae. The fossil genera included by Wright & Collins range from Lower Aptian to Cenomanian; *Binkhorstia* is Maastrichtian. I have included in the subfamily Tymolinae the Upper Eocene *Falconoplax* Van Straelen, 1933. Its sternum is flat and wide, with a deep abdominal depression and well marked sternal grooves between sternites 4–8 and a deep furrow in the anterior portion of sternite 8 of the female. On the criteria used by Guinot for suprageneric taxa it would seem necessary to exclude this genus. The Tymoloidea, according to Guinot (1978) with one family Tymolidae, comprise 2 subfamilies Tymolinae Alcock, 1896 and Cymonominae Bouvier, 1897, in which the living genera *Cymopolus* A. Milne Edwards, 1880 and *Cymonomus* A. Milne Edwards, 1880 are included. They have a square, rugose, granulate or spinose carapace, a narrow, triangular, pointed rostrum, reduced eyes or fixed eyestalks without cornea, in addition to other characters which are not discerned in fossils. They live in deeper water, from 134 to 1269 m (Ihle 1916) and some are abyssal. It seems undesirable to attach a varied and widely distributed group of shallow-water crabs with a spatulate rostrum, large, apparently normal eyes and a tymoline sternum to a minor group of small deep-water crabs which, as we shall see, are not their only descendants. I propose to

separate the Cretaceous genera *Torynomma*, *Dioratiopus*, *Mithracites*, *Binkhorstia* and provisionally *Eodorippe* as a new family Torynommidae which appears to be a more "natural" taxon for them in the sense that its recognition helps the discussion of its relations. Those with Homoloidea and Prosopidae remain to be clarified after further studies of their Jurassic representatives and, if possible, of the Hauterivian "?*Glaessneria*" *gignouxi* (Van Straelen) mentioned by Wright & Collins (1972, p.35). However, this single, fragmentary specimen, of uncertain provenance, can no longer be found (R. Förster, pers. comm. July 1980). Relations to Dromiidae and Dynomenidae with which their living descendants have been compared do not appear to be close. The Torynommidae are probably ancestral to Tymolidae (Cymonominae+Tymolinae) and possibly also Dorippidae and Palicidae, similar to relations depicted in Bouvier's phylogenetic diagram (Bouvier 1897, A. Milne Edwards 1902, p.106) where their place is taken by unspecified "Dynoméniens".

Diagnosis of the family Torynommidae: Carapace square, rectangular or pentagonal in outline, convex, front spatulate, projecting, not strongly deflexed; regions well marked by grooves including the branchiocardiac; lateral margins not sharp, side walls steep, eyes well developed, retractable into shallow orbits. Sternum triangular anteriorly, oval in outline posteriorly, with the last sternites vertical and chevron-shaped. It resembles the sternum of the Tymolinae and Homolidae rather than the configuration of the sternum in the Dromiacea. Where known, the gonopores are coxal (heditreme). Chelipeds subequal, second and third pereiopods long and strong, fourth and fifth (or the fifth only) in dorsal position and much reduced. Abdomen with first somites exposed dorsally. Cretaceous (Aptian to Maastrichtian).

Torynomma Woods, 1953

Torynomma (Torynomma) flemingi nov. sp.
FIG. 9

Derivation of name: After Sir Charles Fleming F.R.S., who has made outstanding contributions to the palaeontological knowledge of New Zealand.

Holotype material: Victoria University, Wellington, No. VA122.

Locality: Koutu Point, Hokianga Harbour (Loc. V2114), New Zealand.

Age: Upper Senonian-Maastrichtian, Mata Series.

Description: Carapace slightly convex, approximately square in general outline, about 30 mm long and wide. Anterolateral margins almost straight, posterolateral margins which are damaged were slightly convex, width of carapace across antero- and posterolateral margins was about equal but reduced about middle of its length. Orbits large, very shallow; orbital margin straight, transverse. Extraorbital tooth conical, pointed, directed diagonally forward, outward and upward. Regions and lobes well marked. One small tubercle on anterior mesogastric lobe, one pointed tubercle on its centre. Posterior gastric pits clearly marked. All other spinose tubercles arranged symmetrically: 1 on each side of the hepatic, metagastric and cardiac lobes, 2 on each protogastric and epibranchial lobe. Branchial regions granulate. Carpus and merus of the cheliped have sharp dorsal ridges. Chelipeds robust, subequal. Fourth and fifth pereiopods very weak.

Remarks: This species differs from *T. quadratum* Woods (Fig. 8) in its size and the shape of the carapace which is flatter and has a squarish outline. The spines on the surface are more numerous and much more prominent.

Paratorynomma nov. subgen.

Type species *Torynomma (P.) dentatum* nov. sp.

This subgenus differs from *Torynomma* Woods in its flatter and wider carapace with a less deflexed rostrum and a strongly and evenly granulated surface. Its most obvious difference is seen in the prominent anterolateral extraorbital teeth which are triangular, directed forward and outward, and mark the greatest width of the carapace. The chelae are more slender and elongate and the chelipeds are longer. It differs from *Dioratiopus* by its almost straight fronto-orbital margin and slightly converging posterolateral margins but resembles it in its granulate surface sculpture and elongate chelae.

Torynomma (Paratorynomma) dentatum nov. sp

FIGS 10–11, 20

Derivation of name: from the conspicuously dentate fronto-orbital margin.

Material: Holotype P22930 and Paratypes P22931 (Locality 1), P22936, P22941,

P22943 (Loc. 2); P22944 (Loc. 3), P22942 (Loc. 4). Collected by B. Daily 1954.

Localities: South coast of Bathurst Island, north of Darwin, Northern Territory. Beach cliffs and shore platform. Loc. 1–3 are 16–25 km SW of Bathurst Island Mission. Loc. 1: 2.5 km E of Moonkinu Creek, Loc. 2: Meadinga, E of Moonkinu Creek, Loc. 3: Pouplimadurie Point, about 4 km E of Moonkinu Creek; Loc. 4: Palliamandera Creek, central south coast, 35 km W of Bathurst Island Mission.

Age: Upper Cenomanian, Bathurst Island Formation, Moonkinu Member, from 3 m above to 5 m below "Tapara Bed" with *Acanthoceras* etc. (see Wright 1963, p.612) at Loc. 1–3. Also from Lower Turonian, upper part of Bathurst Island Formation with *Collignoniceras* cf. *woolgari* (Mantell): Loc. 4. All from glauconitic sands and clays.

Preservation: Most of the 8 specimens examined are exceptionally well preserved and most were almost complete when embedded in the sediment but the shell is in various stages of decortication. The fragile shell and formation of incipient concretions around the bodies, a common feature of the preservation of decapod crustaceans in clays and silts, makes complete preparation difficult. There is little distortion and most specimens show little movement between the carapace and the rest of the body. In several specimens a gap of a few mm between carapace and abdomen and opening of the pleural suture indicates that they are probably moults. Seven specimens are preserved in grey silty clay, one in glauconitic sand. There is no doubt that they lived where they were buried.

Description: Carapace rectangular in outline, wider than long, with a straight fronto-orbital margin; gently convex longitudinally and almost flat transversely. No distinct lateral edge, side walls vertical; posterior margin sinuous. Front projecting only a short distance forward but deflected downward, with median groove and pair of short basal spines. Pointed, conical, supraorbital spine about equidistant from front and conspicuous extraorbital-anterolateral tooth. This is triangular in outline, with flat surface, drawn out into a long, sharp, anterolaterally directed spine. Its anterior margin bears 3–4 small tubercles and its tip is granulated. Surface of carapace uniformly granulated, with only few more prominent tubercles and few smoother areas such as furrows and surface of anterolateral teeth. Cervical, hepatic and greater part of the branchiocardiac furrows about equally well marked. Another posterolaterally directed groove connects cervical and branchiocardiac furrows and divides epibranchial lobes. Meso- and metabranchial lobes divided medially by a longitudinal groove extending through the faintly delimited urogastric lobe into the cardiac region. Meso- and metrabranchial lobes confluent. Orbits very large and shallow, eyestalks unusually robust with smooth surface. In one specimen a part of what appears to be an antennal stalk projects forward from below the supraorbital tooth for about half the distance separating front from anterolateral tooth. Its proximal portion cannot be freed without damage to the anterior part of he carapace.

The shape of the sternum (Fig. 11) is distinctive. It is generally flat but with sternite 7 (and consequently also 8 which is not preserved) turned upward. All sutures except 1/2 and 4/5 complete and crossing the midline. End of female abdomen extends to a ridge on sternite 4+5. Male abdomen unknown. Gonopores could not be recognised with certainty in this species. A third maxilliped preserved in one specimen shows the elliptical outline of the merus, with subterminal articulation of the carpus. Chelae of the P1 subequal, with elongate rectangular propodus, covered with spiny granulations which tend to be aligned in 2 rows on its upper edge. Fingers as long as the propodus and gently curved. Fixed finger deflexed slightly downward. Merus and carpus spinose. P2 and P3 about equally strong and long, with upper and lower rows of spines on the podomeres. Their length exceeds 20 mm, with a diameter of up to 5 mm. P4 and P5 thin, cylindrical, with a diameter of about 1 mm, smooth, articulated above the bases of the P3.

Dioratiopus Woods, 1953

Type species *D. salebrosus* Woods

Dioratiopus Woods, 1953, p. 52; Wright & Collins 1972, p. 33, 34, 42

Doratiopus Woods, Glaessner 1969, p. R492 (erroneous spelling).

Glaessneria Wright & Collins 1972 (non Takeda & Miyake 1964), p. 34 ff.

Glaessnerella Wright & Collins 1975, p. 441.

As noted by Wright & Collins (1972, p. 33), "the genera *Glaessneria* nov. and *Dioratiopus* Woods are closely allied". The authors state that the species of their new genus are dis-

tinguished from the Australian *Dioratiopus* by being "much flatter in both transverse and longitudinal section". They "lack the inner oblique sulcus on the mesobranchial area and have more strongly spinose frontal areas". The diagnostic validity of these characters must be questioned. While some of the English species are much flatter than the Australian type species, this is not correct for the European type species "*G.*" *spinosa* (Van Straelen 1936) which is more convex transversely and only insignificantly less so longitudinally, except for the raised sides of its rostrum. The oblique furrow on the branchial area is present in *Dioratiopus*, though possibly less pronounced laterally where it joins the branchiocardiac sulcus. The generally weaker development of carapace furrows in *Dioratiopus* cannot be considered as a reliable generic character, and the same applies to the less "spinose frontal areas" which are almost without spines in several European species. Small basal rostral, supraorbital and extraorbital/anterolateral spines are present in *Dioratiopus*. The generic identity of European and Australasian mid-Cretaceous decapod crustaceans is not anomalous but is found in *Homolopsis*, *Notopocorystes* and *Hemioon* among the Brachyura and in Macrura. The species *Homolopsis dawsonensis* Bishop, 1973, which does not have a *linea homolica* was considered by its author to resemble *Homolopsis depressa* Carter but to differ "by being even less ornamented (having no areoles), having a continuous sagittal ridge, having more inflated branchial regions, and a broader cardiac-intestinal region" (Bishop 1973, p. 20). These are specific differences from "*Glaessnerina*" *depressa* which is a *Dioratiopus*. Bishop's species extends the range of this genus to the Maastrichtian Pierre Shale of Montana.

Dioratiopus salebrosus Woods, 1953

FIG. 12, 12A

Dioratiopus salebrosus Woods, 1953, p. 53, pl. 2, fig. 4, 5, text-fig. 2.

Doratiopus salebrosus Woods, Glaessner 1969, p. R492, fig. 304 (2)

Material: One specimen collected and presented by H. Wopfner and D. Scott on behalf of Geosurveys of Australia No. P22933.

Locality: Wooldridge Creek (=Fossil Creek), a tributary of the Alberga River, about 40 km NW of Oodnadatta, South Australia.

Age: Upper Albian, Marree Formation (See N. H. Ludbrook, Bull. 40, Geol. Survey S. Aust., 1966, p. 38, Map 4).

Remarks: The specimen is preserved in part of a hard concretion as an external mould, showing the almost complete carapace and fragmentary pereiopods. It agrees completely with the holotype in type in size, shape and ornamentation

Dioratiopus sp.

FIG. 21

Material: One specimen, P22928, collected by B. Daily 1954.

Locality: South coast of Bathurst Island N of Darwin, Northern Territory. Poupanderi Point, about 16 km SW of Bathurst Island Mission

Age: Upper Cenomanian, Moonkinu Member of Bathurst Island Formation, within about 1 m below the base of the "Tapara Bed".

Preservation. A poorly preserved carapace in a ferruginised concretion containing also scattered remnants and external moulds of pereiopods.

Description: Carapace subrectangular, sides slightly converging toward the front. About 21 mm long, 16 mm wide and 7 mm high. Surface gently rising for about 5 mm from base of rostrum, generally flat longitudinally, gently convex transversely. Greatest width appears to be at level of posterior end of cardiac region. Regions of carapace as in type species; spines apparently placed as in *Homolopsis edwardsi* Bell but almost obliterated by erosion and probably originally less prominent. Surface finely granulated. Orbital depressions below the hepatic lobe, smaller than in the type species. Chela with rows of granules on propodus and carpus and with slender, curved dactylus.

This species differs from *H. spinulosa* in some details of outline and in its weaker ornamentation. The specimen is insufficiently preserved for a specific diagnosis but the presence of an additional species in the Bathurst Island Formation is of interest.

Eodorippe nov. gen.

Type species *E. spedeni* nov. sp.

Diagnosis: Characters as described for the type species.

Eodorippe spedeni nov. sp.

FIG. 13, 13A

Derivation of name: After Dr I. Speden, Geological Survey of New Zealand, who sug-

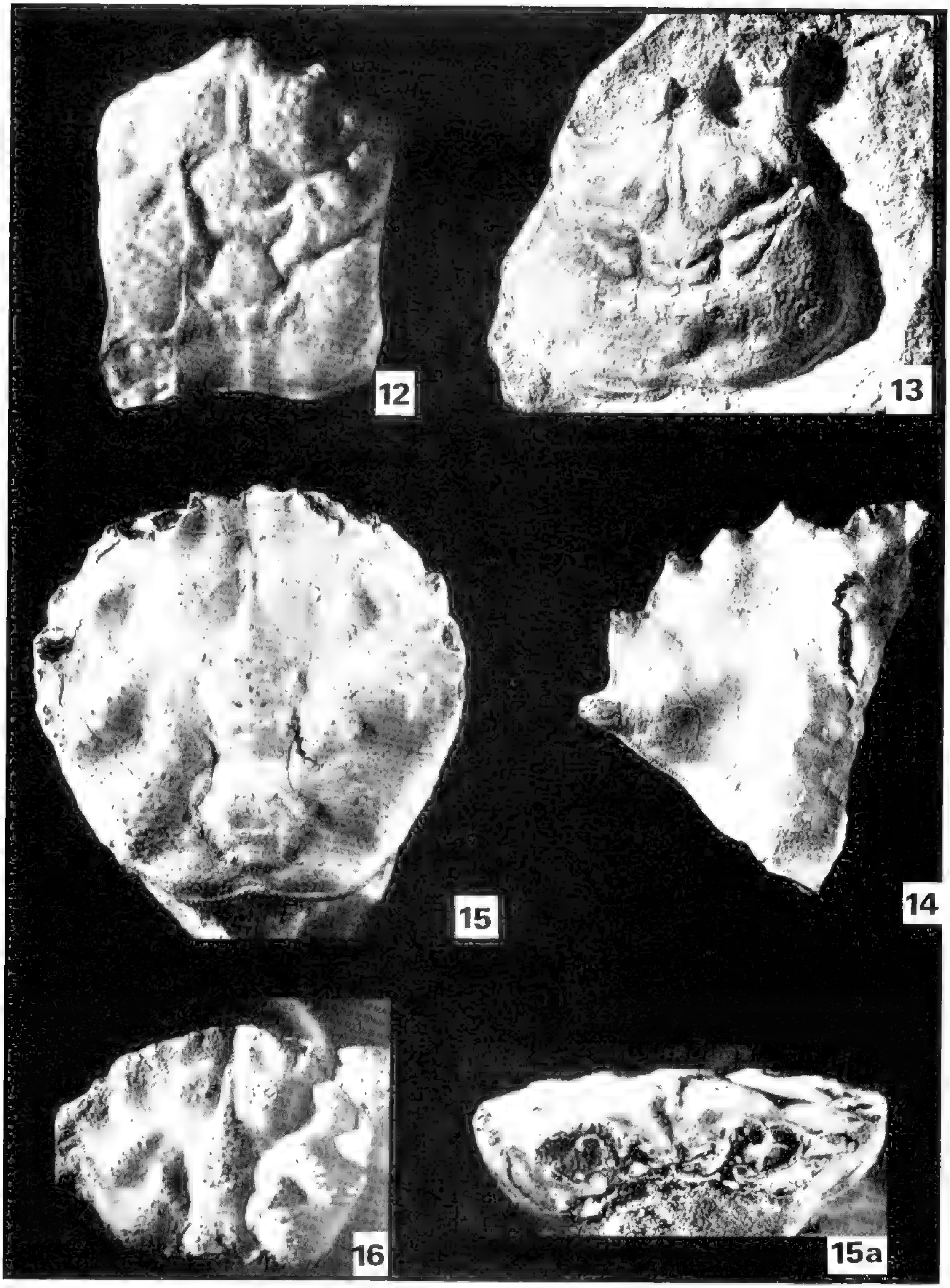
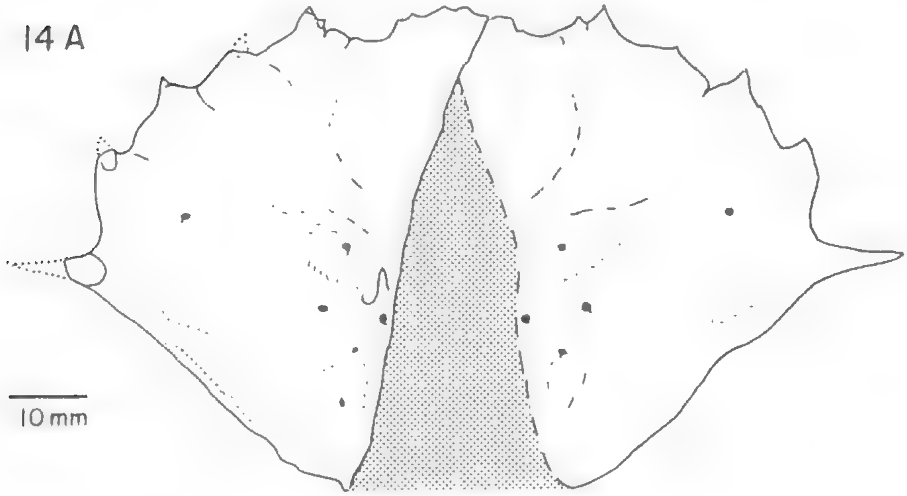
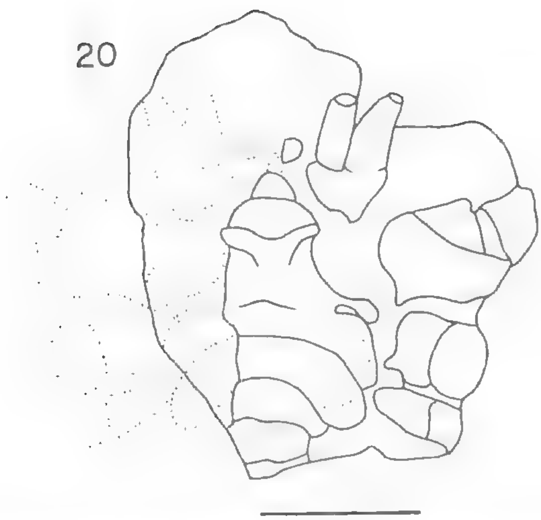


Fig. 12. *Dioratiopus salebrosus* Woods. Artificial cast of carapace of specimen P 22933. x2.
Fig. 13. *Eodorippe spedeni* nov. sp. x2.
Fig. 14. *Rhachiosoma granuliferum* (Glaessner). x1.
Fig. 15, 15a. *Pororaria eocenica* nov. sp. Holotype. 15 dorsal view, 15a—frontal view. x2.
Fig. 16. *Pororaria eocenica* nov. sp. Paratype DC 361, x2.





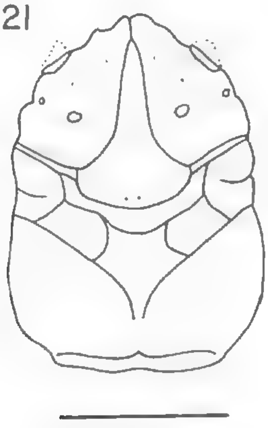


Fig. 14A. *Rachiosoma granuliferum* (Glaessner) Diagrammatic reconstruction of carapace.
Fig. 20. *Torynomma* (*Paratorynomma*) *dentatum* nov. sp. Paratype P 22936, sternum and appendages, showing tip of mandible, basal parts of Mx3, P 1–3; right side reconstructed in outline.
Fig. 21. *Dioratiopus* sp. Carapace reconstructed.

gested the investigation of specimens from New Zealand and assisted with information.

Material: One specimen, N.Z.G.S., AR 675. Collected by Mrs J. Wiffen.

Locality: Stream boulders from bed of Mangahouanga Stream, a tributary of the Te Hoe River, from between bridge and waterfall. Loc. No. N 104/f 909, Grid ref. N 104/261088.

Age: Campanian-Maastrichtian (Pripauan-Haumurian).

Preservation: Carapace showing dorsal aspect and left flank almost completely preserved, with fragments of shell adhering to surface of internal and partially preserved external mould.

Description: Shell thin, carapace transversely oval in outline, very moderately convex longitudinally and transversely. Greatest width across mesobranchial and cardiac lobes. Rostrum long and narrow, spatulate, pointing forward; small granules on each side of its

base, upper surface with a longitudinal depression, lower surface ridged. Fronto-orbital margin long, transverse. Its inner portion, occupying less than half its width ends laterally in a small, gutter-like depression; outer portion has a smooth, rounded, prominent edge. Infraorbital margin projects beyond upper surface, orbital depressions large and shallow and no suborbital tooth was observed. Extraorbital-anterolateral teeth turn sharply forward, ending in short, pointed spines. Rounded anterolateral margin bears a small hepatic spine and leads to a pronounced sinus in which cervical and branchiocardiac furrows meet, continuing down the flank as a single, straight groove. Behind the incision there is a short, sharp ridge. It begins with a short spine and is directed in an outwardly concave curve backward and outward, slightly above the rounded true lateral carapace periphery. Carapace narrows slightly behind end of ridge. Posterolateral and posterior margins sinuous and marked by a smooth ridge. Concave median part of the posterior margin short. Surface of carapace prominently marked by transverse furrows and a few tubercles. Cervical furrow sinuous and medially interrupted; branchiocardiac furrows straight, convergent but become unclear near the cardiac region. Between cervical and branchiocardiac furrows a pair of intermediate oblique grooves are the most distinctive character of this carapace pattern. They are lateral extensions of a groove between the meso- and metagastric lobes which are bisected by a weaker median (longitudinal) furrow. Anterior and posterior portions of the dorsal surface are undivided by grooves and are convex on each side. Protogastric lobes bear three tubercles each, spaced about equally along an arc in front of the cervical groove, leading to hepatic spine. Mesogastric lobe, bounded by straight lines, extends a long and very narrow tongue forward. An elongate anterior and a shorter posterior epibranchial lobe on each side, the anterior ending in a small marginal tubercle in the junction of the main transverse grooves, the posterior is shorter, obliquely triangular in outline, and sharply delimited from the metagastric lobe. A faint, medially interrupted, transverse ridge and some granulation on the anterior part of the ill-defined cardiac region. Surface minutely granulated, with some coarser granules on the mesobranchial lobes.

Remarks: There are some similarities in shape of the carapace and the orbits between the new species and *Mithracites vectensis* Gould from the Lower Aptian of England. The differences in the pattern of the transverse furrows, the shape of the mesogastric lobe, the narrow rostrum and the lack of the coarse ornamentation in *Eodorippe* justify a generic distinction.

Systematic position: Withers (1951) placed *Mithracites* in the Prosopidae, a view rightly criticised by Wright & Collins (1972, p. 40). They point with some justification to certain similarities with "*Glaessneria*", here placed in the synonymy of *Dioratiopus*, and consequently include it in the family Cymonomidae. The Late Cretaceous new genus has some similarities with Cymonominae. The lack of information on the morphology of the ventral side of the cephalothorax of *Eodorippe* makes its placing in a modern classification difficult. In the absence of more complete specimens we cannot decide whether this new genus is peditreme or sternitreme and whether it is oxystomatous. Despite the absence of such information the striking resemblance between the carapace of *Eodorippe* and the genus *Dorippe* cannot be disregarded. It is seen not only in trivial generalities of shape and ornamentation which can be due to common convergences but in details which are unique and cannot be dismissed. The sinuosity of the wide posterior-posterolateral margin can be interpreted as indicating a position of the third and fifth pereiopods similar to that in *Dorippe* (the bases of the third pereiopods do not affect the shape of the carapace margin). The lateral convergence of the cervical and branchiocardiac grooves resembles closely the pattern in several species of *Dorippe* (*D. facchino* Herbst, *D. japonica* von Siebold, *D. granulata* de Haan) while the intermediate transverse groove appears to be present in *D. dorsipes*. The position and shape of the shallow orbits, the divided supraorbital margin and the extraorbital teeth are also similar. If the classification of Guinot (1978) is followed and the Palicidae are placed with the Dorippoidea, some resemblances between *Eodorippe* and *Palicus* Philippi, 1838 become significant: the great width across the mesobranchial lobes, the unusual multiplication of the transverse grooves, and the development of a sagittal mesogastric and metagastric furrow. Significant differences are the apparent absence of the prominent infraorbital teeth of *Dorippe* and the shape of the rostrum. This shape makes it unlikely that *Eodorippe* had reached the oxy-

stomatous condition of *Dorippe* with its dorsally visible exhalent opening. It agrees with this structure in the Tymolidae and Torynommidae. The known characters of *Eodorippe* suggest a derivation of the Dorippoidea from Tymoloidea. This hypothesis remains to be tested by a study of the still unknown ventral structures of the cephalothorax of *Eodorippe*. It is tentatively attached to the Family Torynommidae.

Family Portunidae

Rhachiosoma granuliferum (Glaessner, 1960)

FIG. 14, 14A

Portunites granulifer Glaessner 1960, p. 21, pl. 3, fig. 7, text fig. 9.

New locality: Coastal cliff at Pororari, 2.4 km N of Punakaiki, Grid ref. S37/723, c852318.

Material and preservation: The incomplete left half of a carapace, broken from the right half of the front to the posterior margin above the fifth left pereiopod. The anterolateral teeth 2–5 are damaged. Most of the shell surface is preserved. Canterbury Museum, Christchurch, New Zealand, No.zfc 9, coll. R. S. Allen, Feb. 1935.

Age: Upper Eocene, Kaiatan-Runangan. The holotype was from the Middle Eocene.

Remarks: Further studies of the type species of *Portunites* (*P. incertus* Bell) suggest that the original generic assignment of the species *granulifera* was inappropriate. Prominent lateral spines are equal to almost half the width of the carapace in *Rhachiosoma bispinosum* Woodward, 1871 from the Lower Eocene London Clay, but less than a quarter of that width in *R. granulifera*. However, the orbits and carapace sculpture are similar. The new, fragmentary specimen has weaker and probably fewer tubercles on the carapace surface than the holotype but until new and more complete material is found, these differences are insufficient for the establishment of a new taxon. The classification of these fossils should be reviewed when the ventral aspect and pereiopods are known.

Family uncertain

Pororaria nov. gen.

Type species *P. eocenica* nov. sp.

Diagnosis: Characters as described for the type species.

Pororaria eocenica sp. nov

FIGS 15, 15, 16

Material: Two almost complete carapaces. Holotype (including right chela). New Zealand Geological Survey collection DC 360, paratype DC 361. Also fragments of carapaces, chelae and walking legs and one carapace with both chelae. Canterbury Museum, Christchurch, New Zealand, No. zfc 31–38, coll. R. S. Allen Feb. 1935.

Locality: Cliffs at Pororari, 2.4 km N of Perpendicular Point, Punakaiki (zfc 31–38); 800 m S of Perpendicular Point, Map Sheet S 37/735, N.Z. Geol. Survey locality GS 10490 (DC 360–361)

Age: Upper Eocene, Kaiatan-Runangan.

Description: Carapace as long as wide, outline oval to hexagonal, very slightly convex to flat surface smooth with localised concentrations of granules. Front with a median notch and on each side 1 strong and 2 weak teeth. Orbits as wide as the front, with supraorbital granulations and 2 notches, with a gap between the large antennal base and an infraorbital tooth. Antennular bases folded back obliquely. About 5 anterolateral teeth, obscured by marginal granulations. Posterolateral margin starts from a ridge behind last lateral tooth but not delineated on the inflated mesobranchial lobes. Cervical groove well defined, starting from posterogastric pits and delimiting on each side in three forwardly concave arcs the mesogastric, protogastric and hepatic lobes. These are equally well defined by hepatic grooves. There are conical tubercles on hepatic lobes; groups of spinose granules on meso-, proto- and metagastric, epi-, meso- and metabranchial, and cardiac lobes. Epibranchial field of granules has an unusual U-shape which resembles similarly placed granulations in *Dakoticancer* Rathbun. As in this genus, a branchiocardiac groove crosses rounded lateral margin behind this granulated lobe. Urogastric lobe finely pitted and rectangular, cardiac region broadly hexagonal. Posterior margin has a strong, granulated ridge with a slight median forward bend. Chelipeds are strong and heterochelous. Carpus with spine near its inner distal angle. Inflated propodus has smooth inner and granulated outer and upper surfaces. Granules tend to be arranged in longitudinal rows. Fingers shorter than the upper length of the propodus, strong, minutely granulated, grooved

but otherwise smooth. Walking legs preserved as scattered fragments which are thin and long.

Systematic position: In the absence of complete pereiopods and of the sternum it is difficult to reach a definite conclusion about the assignment of this new genus to an existing higher taxon. It resembles the less advanced Portunidae such as some Carcininae (*Nectocarcinus, Carcinus*) in the general shape of the carapace and in some characters of its fronto-orbital region. *Nectocarcinus* shows a similar transition from anterolateral teeth to groups of spiny granules. The chelipeds are also similar. Thin, long legs do not occur in Carcininae and the lobes of the posterior half of the carapace are different. There are also resemblances with Atelecyclidae among the Corystoidea but the relevant details of the fronto-orbital region are not well enough preserved in the genus to allow a definite conclusion about portunoid or corystoid affinities; the configuration of the posterolateral portion of the carapace does not favour the latter but the chelae are cancroid. A similarity of the carapace with that of *Avitelmessus* Rathbun does not apply to its median portion which shows a corystoid pattern. *Avitelmessus* is very close to *Dakoticancer*. As Guinot (1978) remarked, these genera should not be assigned to the Dromiacea. Whether *Pororaria* is related to Corystoidea or Portunoidea remains to be elucidated. Until further evidence is found, the new genus is tentatively placed in the superfamily Portunoidea.

Family Panopeidae

Panopeus H. Milne Edwards, 1843

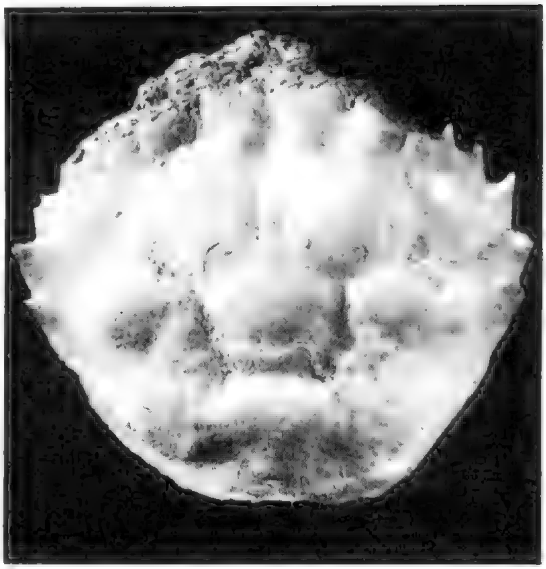
Type species *P. herbsti* H. Milne Edwards

Panopeus whittenensis nov. sp.

FIGS 17–19

Material: More or less complete carapaces, chelae, fingers, and fragments of legs. Holotype P22935, paratypes P22938, 22939, 22946–22950.

Localities: Whitten Bluff, S of Christies Beach, 28 km SSW of Adelaide (type locality and most common occurrence). Also from



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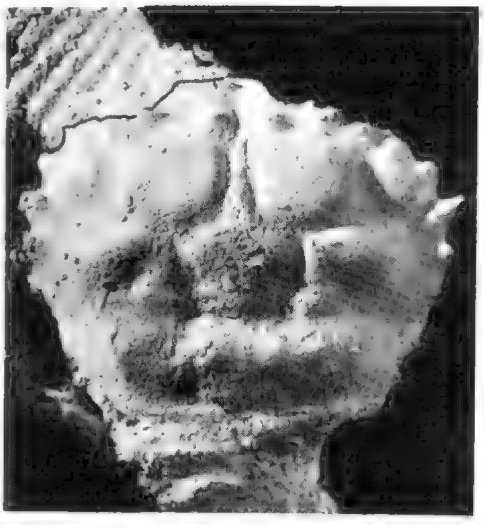

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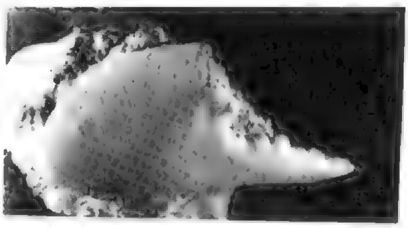

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Fig. 17. *Panopeus whittenensis* nov. sp. Holotype, x3. Posterolateral margins restored.

Fig. 18. *Panopeus whittenensis* nov. sp. Paratype P 22938, x2.

Fig. 19. *Panopeus whittenensis* nov. sp. Right chela, specimen P 22939, x2.

Maslin Bay, about 15 km further south. Coastal cliffs on the E shore of Gulf St Vincent (P22938, coll. Dr M. Buonaiuto)

Age: Upper Eocene, upper Tortachilla Limestone and base of Blanche Point Formation (= "Transitional Marl"). Planktonic foraminiferal zone 15.

Preservation: Some complete and some broken carapaces without branchiostegites, sternum, abdomen, or attached appendages. The propodus of the cheliped may have the dactylus and parts of the carpus attached but more often it is disjointed. Small fragments of pereiopods apparently belong to this species. The only other decapods found with *Panopeus*, in a rich shallow-water fauna of cirripeds, bryozoans, brachiopods, echinoderms, serpulid worm tubes (some attached to carapaces and claws of *Panopeus*) and numerous mollusca are one incomplete dromiid carapace (*Dromilites*? sp.), a few claws of an oxyrhynchous crab, and chelae of a callianassid.

Description: Carapace slightly wider than long, convex. Frontal margin straight, with median indentation and transversely grooved and finely granulated edge. Orbits well developed, with inner supra- and infraorbital teeth, evenly granulated edges and 2 supraorbital fissures. Anterolateral margins with 5 conical teeth of which the fourth is the strongest and most prominent and the fifth the weakest. Posterolateral margins converging backward. Posterior margin wide, with raised, faintly granulated rim. Main regions of the carapace surface well marked by shallow grooves. Posterior gastric pits clearly visible. Surface appears to be smooth when well preserved, becoming granulated with decortication by weathering. Some individual variability in ornamentation. No remarkable features in the pattern of regions except perhaps strong development of the epigastric and metagastric lobes. Right chela strong, propodus smooth, with a very faint depression below the upper edge and two rows of pits above and along lower edge of fixed finger. A row of irregularly sized and blunt teeth on its upper edge. Lower edge of the propodus and finger strongly curved to fit snugly along the anterior margin cephalothorax. The carpus is square.

Measurements (in mm): Lengths and widths 17.8 and 22.5, 22 and 26, 20.5 and 23, 22.5 and 28. In the carapace which is 20.5 mm long, the frontal margin has a half-width of 4 mm and the orbit was 4.5 mm wide. In a carapace which was about 20 mm long and 24 mm wide, the orbit was about 5 mm wide. A large propodus with fixed finger is about 35 mm long and 18 mm high.

Remarks: In the absence of any parts of the ventral surface of the cephalothorax or appendages other than the large claw, the precise systematic position of this crab remains in some doubt. The absence of transverse raised lines on the carapace would distinguish it from the living species of *Panopeus* for which their presence is a convenient diagnostic character. It would not necessarily exclude it from the evolutionary lineage of this genus which has been reported from the Paleocene and Eocene. The new species as far as known, is morphologically closest to *Panopeus* and therefore assigned to it, pending discovery of other still missing parts.

Phylogenetic conclusions

The phylogenetic significance of several of the new Cretaceous and Tertiary crabs here described has been briefly mentioned. It can now be considered in the framework of the adaptive radiation of the Brachyura (Fig. 22, see also Glaessner 1980). This updated version of a phylogenetic diagram which I first published 50 years ago (Glaessner 1930; 1960, Fig. 22) incorporates some of the results of the monographic work of Wright & Collins (1972) on British Lower Cretaceous crabs and reflects the new classification of the Brachyura by Guinot (1977, 1978) and other important studies which are considered in it. Certain modifications and re-arrangements of this classification are suggested as a result of the present investigation.

The new family Torynommidae may have evolved ultimately from the family Prosopidae of the Homolodromioidea, as implied by Wright & Collins (1972) and probably from archaeobrachyuran descendants, the Homoloidea, in Late Jurassic-Early Cretaceous or in Mid-Cretaceous time. Their living descendants are related to them in a manner depicted with remarkable foresight by Bouvier as early as 1897. They also may have given rise to the Late Cretaceous Carcineretidae which acquired an early adaptation to swimming. From similar origins in the podotrematous Homoloidea the well documented Necrocarcininae-Calappinae lineage (Förster 1968) and possibly Orithyidae (see Guinot 1978, p.255) evolved and and eventually attained the heterotrematous grade. Their Mid-Cretaceous descendants, the

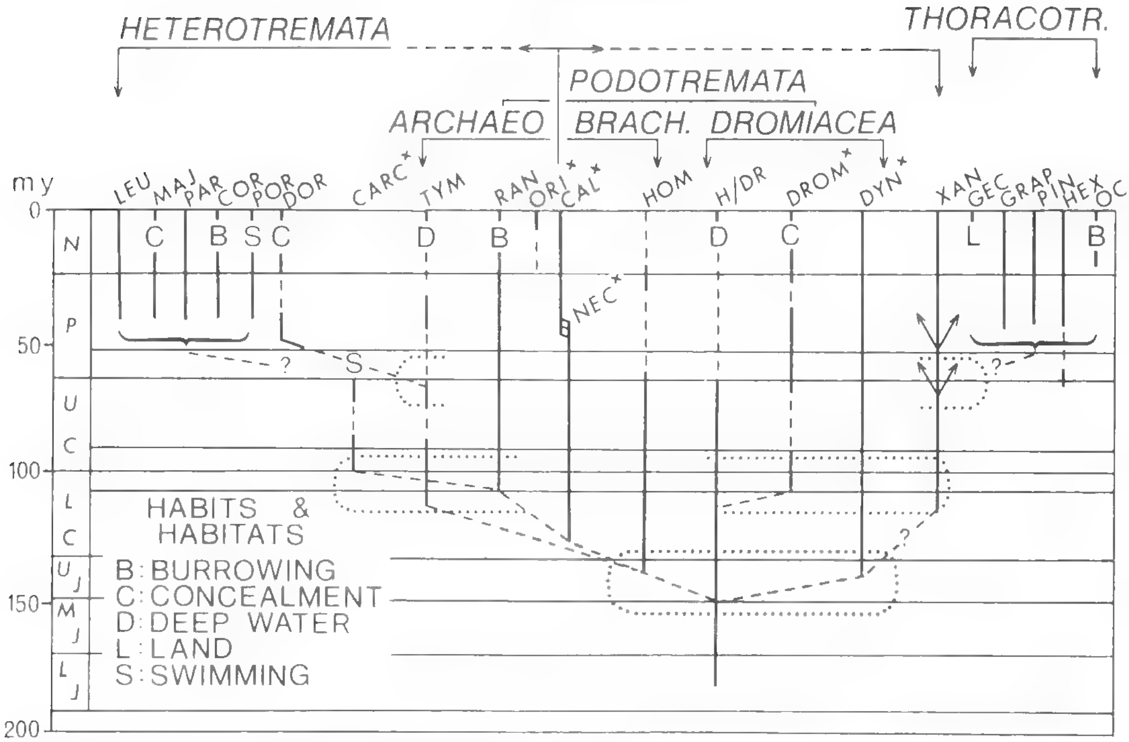

Fig. 22. Adaptive radiation of the Brachyura.
Superfamilies (and lower taxa marked with *): LEU Leucosioidea, MAJ Majoidea, PAR Parthenopoidea, COR Corystoidea, POR Portunoidea, DOR Dorippoidea, CARC* Carcineretidae, TYM Tymoloidea, RAN Raninoidea, ORI* Orithyidae, CAL* Calappidae, NEC* Necrocarcininae, HOM Homoloidea, H/DR Homolodromioidea, DROM* Dromiidae, DYN* Dynomenidae, XAN Xanthoidea, GEC Gecarcinoidea, GRAP Grapsoidea, PIN Pinnotheroidea, HEX Hexapodoidea, OC Ocypodoidea. Geochronometric (in million years, my) and stratigraphic scales at left. N Neogene, P Palaeogene, UC Upper Cretaceous, LC Lower Cretaceous, UJ Upper Jurassic, MJ Middle Jurassic, LJ Lower Jurassic. Note that top of Paleocene is shown within Palaeogene, and Albian and Cenomanian are marked below and above line dividing Cretaceous. Dotted lines mark the three periods of major diversification of the Brachyura.

Raninidae, adapted to burrowing and remained at the podotrematous grade. The discovery of *Eodorippe* strongly suggests a Late Cretaceous origination of the heterotrematous Dorippidae from Tymoloidea, as foreseen by Bouvier. This is still subject to confirmation by more complete material.

The origins of the remaining Heterotremata are still unknown, probably diverse, and dated mostly Late Cretaceous to Early Tertiary. Wright & Collins (1972) conclude that the Xanthidae were derived from Dynomenidae in Late Jurasic-Early Cretaceous time. This derivation cannot apply to other Heterotremata which show no signs of origination from Dromiacea or indeed of pre-Tertiary existence. It is possible that further studies of *Pororaria* may clarify relations with or between Portunoidea and/or Corystoidea (a prior synonym of Cancriformia). Some members of these two superfamilies show a dichotomy between habits and adaptations for swimming (as in *Portunus*) as opposed to burrowing (as in *Corystes*). The portunoid adaptations for swimming do not seem to be derived from but rather heterochronously convergent to those of the Carcineretidae. The burrowing habit of the Corystidae is generally considered as a convergent or possibly parallel adaptation compared with that of the Raninidae. The origins of the Leucosiidea and Majidea remain obscure; their adaptations diverge distinctively from those of any other group of crabs.

The Thoracotremata, at the highest grade, include the land crabs and various successful strand dwellers with a variety of habits. They resemble the Xanthoidea more than other Heterotremata but their origin, in the Late Cretaceous or Early Tertiary, is cryptic.

As in all phylogenies, many questions remain, but new material, particularly of Mesozoic and Early Tertiary age, can now be

fitted more easily and rationally into the framework of existing knowledge and classification. Most importantly, the replacement of the traditional but mostly ill-conceived "Sections" with a horizontal classification at the highest level by grades, has improved our understanding of the history of the Brachyura.

Acknowledgments

My thanks are due to Dr B. Daily, Department of Geology and Mineralogy, University of Adelaide, who collected the fossil crabs from outcrops on Melville and Bathurst Island, Northern Territory, and established their stratigraphic position; to Dr I. Speden, Geological Survey of New Zealand; to the authorities of the Victoria Museum, Wellington and the Canterbury Museum, Christchurch, New Zealand, and to Dr Mary Wade, Queensland Museum, Brisbane, for the loan of specimens from collections in their institutions; to Dr N. H. Ludbrook for the loan of a specimen from South Australia and for information, and to Mr C. W. Wright for valuable discussions on British Cretaceous crabs. Dr Danièle Guinot, Muséum national d'Histoire naturelle, Paris, discussed relevant aspects of her work with me and provided essential literature.

All specimens with numbers prefixed P have been deposited in the South Australian Museum, Adelaide. The photographs were prepared by Mr R. Barrett. The skilful drafting of Fig. 22 is the work of Miss A. M. C. Swan, Geology Department, University of Adelaide.

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Postscript

Via Boada (1980) reviewed the evolution of the Ocypodoidea, tracing their origin to the Cretaceous genera *Ophthalmoplax* and *Archaeopus*. I had previously (Glaessner 1969) referred the first to the Carcineretidae and the second, doubtfully, to the Palicidae. Subject to further studies, Via's views suggest interesting possibilities of exploring evolutionary links between Ocypodoidea, certain Dorippoidea, and Carcineretidae. When I received his new data it became possible to identify a Middle to Late Eocene crab from a limestone core from the Ashmore Reef No. 1 Bore off the NW coast of Australia (sent to me in 1968 by Dr P. J. Coleman and the Burmah Oil Company) as at least very close to *Retropluma* as described from rocks of similar age in Spain. It lives now in deep water in the Indian Ocean.

A NEW SPECIES OF CYCLORANA (ANURA: HYLIDAE) FROM NORTHERN QUEENSLAND

BY ERIC VAN BEURDEN & K. R. MCDONALD

Summary

Cyclorana manya sp. nov. from Cape York Peninsula, northern Queensland, is described. It is small compared with known congeners and has close affinities with C. brevipes and C. longipes.

A NEW SPECIES OF *CYCLORANA* (ANURA: HYLIDAE) FROM NORTHERN QUEENSLAND

by ERIC VAN BEURDEN* & K. R. MCDONALD†

Summary

VAN BEURDEN, E. & MCDONALD, K. R. (1980) A new species of *Cyclorana* (Anura: Hylidae) from northern Queensland. *Trans. R. Soc. S. Aust.* **104**(6), 193-195, 28 November, 1980.

Cyclorana manya sp. nov. from Cape York Peninsula, northern Queensland, is described. It is small compared with known congeners and has close affinities with *C. brevipes* and *C. longipes*.

Introduction

In a partial revision of frogs of the genus *Cyclorana* Steindachner, Tyler & Martin (1977) described five new species and raised the total to 10, highlighting the diversity within the genus. We describe a further species from northern Queensland. It resembles *C. longipes* Tyler & Martin but is considerably smaller than this or any other congener.

Methods

The type specimens are lodged in the Queensland Museum (QM), and South Australian Museum (SAM). Measurements were obtained using a pair of Helios dial calipers (to nearest 0.1 mm). Eye to naris distance (E–N) is the distance from the posterior margin of the external naris to the anterior margin of the eye. Internarial span (IN) is the distance between the medial margins of the external nares. Other measurements are as defined and abbreviated by Tyler and Martin (1975): HL = head length, HW = head width, S–V = snout-vent length, TL = tibia length.

Mating calls of two individuals were recorded on a Uher 4000 report tape recorder at a tape speed of 19 cm/sec using a Grampian DP4 microphone. Air temperature was recorded within 3 cm of the frog using a Schultheis mercury thermometer. One call of each individual was analysed using a Kay Model 6061–A Sono–Graph audiospectrograph set on a narrow-band (45 Hz band-pass), and a response curve setting of FL–1. This provided measures of call duration, band spacing, lowest and highest frequency. Pulse repetition rate and fundamental frequency were taken from photographs (Polaroid B & W type 107) of oscilloscope traces using a time scale of 2 msec/cm.

Cyclorana manya sp. nov.

FIGS 1–2

Definition: A small species (male adults 27.2–29.9 mm; female 27.5 mm) with short hind limbs (TL/S–V 0.32–0.38). The head is bluntly rounded and the eyes are large (E/E–N = 1.71). There is no dark head stripe from the tip of the snout to the eye or from the eye to the axilla.

Description: Holotype (QM J34886), an adult male collected between Coen airport and Deep Creek crossing 25 km N. of Coen township (13°52′S, 143°12′E), Cape York Peninsula, Queensland, by E. van Beurden, M. Sabath, B. Easteal, M. Robinson and J. Sparkes on 17.1.1979.

Habitus stout, body globose (Fig. 1). Size small. Head broadly triangular when viewed from above, flattened and broader than long.

Fig. 1. Paratype of *Cyclorana manya* shortly after capture near Coen.

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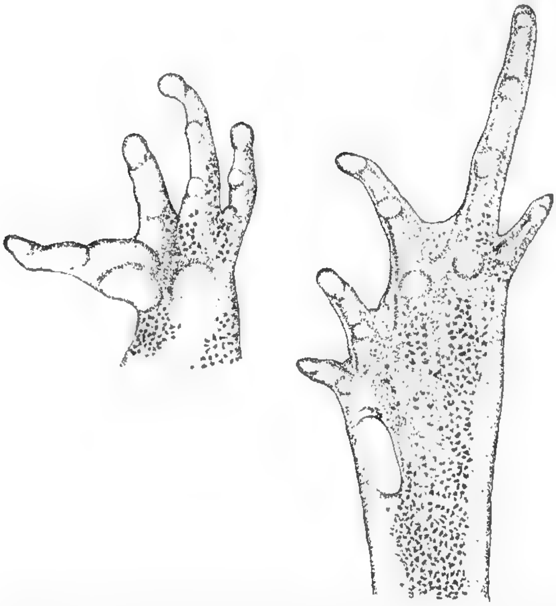

Fig. 2. Palmar and plantar aspects of hand and foot of holotype of *Cyclorana manya* (QM J34886).

Snout rounded when viewed from above and bluntly rounded in profile (HL/HW 0.89). Nostrils inconspicuous and dorsally inclined. Canthus rostralis slightly curved but not prominent. Eye prominent, its width more than 1½ times eye to naris distance. Upper part of iris golden, lower part, silver/grey and anterior and posterior portions black.

Tympanum distinct except for upper and posterior margins which are obscured by supra-tympanic fold.

Tongue ovate, about ½ free behind and just over ½ as wide as gape. Choanae large and widely spaced. Vomerine teeth present on obliquely converging elevations, between posterior margins of choanae.

Fingers short and unwebbed (Fig. 2) without lateral fringes. Subarticular tubercles prominent; paired nuptial pads on each thumb.

Toes slightly webbed. Webbing on medial side of 5th toe does not reach subarticular tubercle at base of penultimate phalanx. Relative toe lengths 4>3>5>2>1. Prominent inner metatarsal tubercles, twice length of first toe (Fig. 2). Hind limbs short (TL/S–V 0.34).

Skin of anterior portion of thigh smooth; that on posterior pitted.

Dorsal body markings of preserved specimen consist of dark grey-brown irregular blotches on lighter brown background. These blotches diminish in size and intensity on flanks and posterior parts of dorsum. A pale, unbroken vertebral stripe runs from tip of snout to tip of urostyle. A broad, light-coloured post-orbital bar crosses head posteriorly at level of tympana. Top of head dark grey-brown while sides, extending down to upper lip, are pale brown.

Ventral surfaces of body and limbs pale cream, as is lower lip. Skin beneath vocal sac darkly pigmented, and skin of abdomen translucent. Posterior region of thigh and flanks pale brown with darker brown blotches.

Dimensions: S–V 29.9 mm; TL 9.5 mm; HL 9.2 mm; HW 11.2 mm; E–N 2.1 mm; IN 1.5 mm; E 3.8 mm; T 1.2 mm.

Variation: Two paratypes: a mature female, QM J34888, and a mature male QM J34889, were collected with the holotype. Twelve further paratypes SAM R17420–R17424; QM J36894–900) including nine mature males, and three immature individuals were collected by R. G. Atherton and K. R. McDonald at the southern end of Coen air strip (13°46′S, 143°07′E) on 6–8.iii, 1979.

The S–V range is 27.2–29.9; the largest specimen being the male holotype. The head is consistently broader than long (HL/HW 0.82–0.96) whilst the nostrils are narrowly spaced (E–N/IN 1.25–1.69). The hind limbs are consistently short (TL/S–V 0.32–0.38).

Colour and pattern are variable. The colour of the dark blotches on the dorsum varies from light grey to a rich, dark brown-grey. The proportion of the dorsum covered by these blotches varies from about 55–85%. The vertebral stripe varies in its conspicuousness and the variation is not consistent with the intensity of blotches.

All specimens larger than 25 mm S–V, except the female, were males with pigmented vocal sacs and nuptial pads. The single female was gravid and contained about 100 eggs, each about 1 mm diameter. Specimens less than 25 mm lacked eggs or male secondary sex characteristics.

Mating Call: The call is a short plaintive bleat of 1.1–1.3 sec. duration (Fig. 3). The dominant frequency is about 2500 Hz and the call consists of 5–8 distinct bands separated by 328 Hz, and ranging 400–3000 Hz. Pulse repetition rate is 294 pulses/sec., and the call is repeated 10–16 times per minute. Calling males were recorded and collected while floating, legs extended, at the surface of shallow

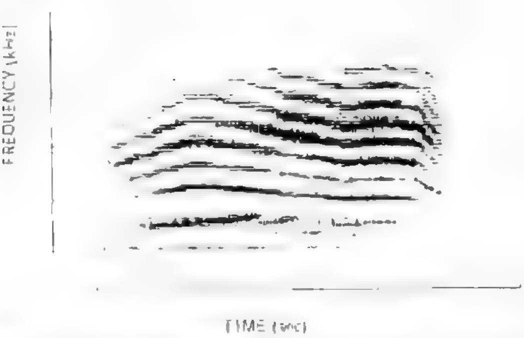

Fig. 3. Audiospectrogram of mating call of *Cyclorana manya* recorded during rain at Coen Airport. (Air temp. 24.8°C, band pass = 45 Hz.)

temporary puddles, in grassy depressions during heavy rains. Air temperature was 24.8°C.

Breeding: The presence of juveniles in March and the calling activity in heavy rainfall suggests that this species is an opportunistic, summer breeder. Little calling was heard on nights when rain was light, and there was none on the dry nights following that on which recordings were made.

Comparison with other species: Comparisons are based on descriptions provided by Tyler & Martin (1977). The most obvious difference between *C. manya* and congeners is the S–V of adult males which is 4.8 mm shorter than the smallest adult previously reported. It also lacks a head stripe from the snout to the eye and eye to axilla. The range of E–N/IN overlaps only *C. longipes*. Call characteristics are most similar to those of *C. brevipes* Gunther. The call duration of the two species is about 1 sec., and the dominant frequency has 3–4 side bands above and below it. The call of *C. manya* differs from that of *C. brevipes* in that the dominant frequency is higher and band spacing is wider. Coloration most closely resembles that of *C. longipes* except that dark head pigmentation terminates at a broad, pale transverse bar extending around the tympanum and down to the axilla.

Four frogs (DT–D 0737–40) taken at Lower Archer River on Cape York Peninsula by J. Thompson in 1933 may represent a form intermediate between *C. longipes* and *C. manya*. Their E–N/IN ratios (1.22–1.25) and bold head coloration are similar to *C. longipes*. S–V (32.2 and 40.7 for the two adults) is intermediate between *C. manya* and the larger *C. longipes*.

Etymology: 'Manya' is the Aboriginal word for 'small' in the local dialect (Wik-munken) at Coen. This is appropriate for the smallest 'water-holding frog' described.

Acknowledgments

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EARLY CAMBRIAN TRILOBITES FROM THE OFFICER BASIN, SOUTH AUSTRALIA

BY J. B. JAGO & B. C. YOUNGS

Summary

Fragmentary trilobites, probably of early Early Cambrian age, occur in the Observatory Hill Beds from the eastern part of the Officer Basin. The trilobites were recovered from limestone core at a depth of 87.85 m in Marla-1, a stratigraphic hole drilled by the South Australian Department of Mines and Energy. Their discovery allows the first reliable macrofossil dating of the Officer Basin sediments in South Australia.

EARLY CAMBRIAN TRILOBITES FROM THE OFFICER BASIN, SOUTH AUSTRALIA

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Summary

JAGO, J. B. & YOUNGS, B. C. (1980) Early Cambrian trilobites from the Officer Basin, South Australia. *Trans. R. Soc. S. Aust.* **104** (6), 197-199, 28 November, 1980.

Fragmentary trilobites, probably of early Early Cambrian age, occur in the Observatory Hill Beds from the eastern part of the Officer Basin. The trilobites were recovered from limestone core at a depth of 87.85 m in Marla-1, a stratigraphic hole drilled by the South Australian Department of Mines and Energy. Their discovery allows the first reliable macrofossil dating of the Officer Basin sediments in South Australia.

Introduction

The Officer Basin is a large intracratonic depression in western South Australia and southeastern Western Australia (Fig. 1). The main part of the S.A. portion covers an area of approximately 100 000 sq. km. and contains sediments ranging in age from Late Proterozoic to Devonian in surface and near-surface outcrops (Fig. 1). Subsurface outliers exist to the east and south of the main basin (Pitt *et al.* 1980). The deep northern parts of the Officer Basin may contain at least 6000 m of sediments.

This paper reports the first trilobites recorded from sediments in the S.A. portion of the Officer Basin. The only previously recorded macrofossil from this part of the Basin is a single specimen possibly representing *Biconulites* (Gatehouse 1976). Prior to the present report, the only palaeontological evidence for the age of any of the basin's sediments came from Devonian microfossils recovered from cores in Munyarai–1[1,2,3] and Early Cambrian microfossils from the Observatory Hill Beds in Wilkinson–1[4]. The specimens figured herein are housed in the palaeontology collection of the S.A. Museum; the catalogue numbers refer to this collection.

Stratigraphy

The stratigraphy of the eastern Officer Basin is summarized in Figure 2. The fauna discussed in this paper was recovered from cores in Marla–1 (lat. 27°28.1′S, long. 133° 44.8′E), a stratigraphic well drilled by the S.A. Department of Mines and Energy in 1974 (Thornton 1978). A more complete section through these beds was drilled during 1979 in Marla–1B (Fig. 3); this well, located near the site of

Fig. 1. Locality map, Officer Basin.

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† Geological Survey of South Australia. Present address: South Australian Oil and Gas Corporation.

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2 Gilbert-Tomlinson, J. (1968). Fossils from Munyarai No. 1 Well, Officer Basin, South Australia. Appendix 7 in S.A. Dept Mines & Energy Rept Book 979 (unpublished).

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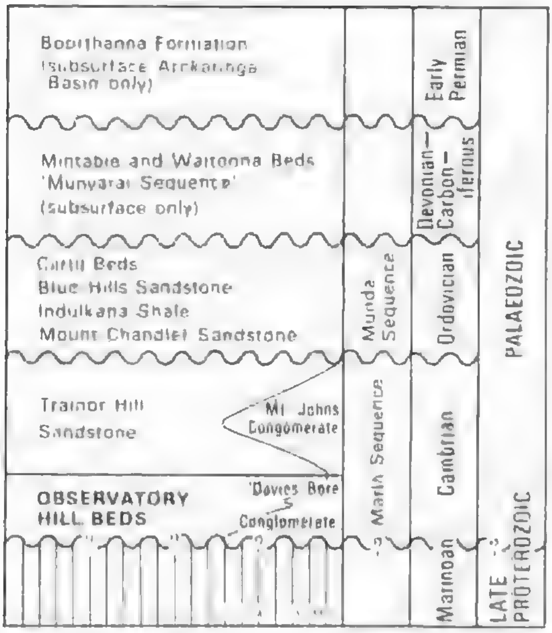

Fig. 2. Simplified stratigraphy, Officer Basin, S.A. (modified after Pitt *et al.* 1980).

Marla–1, intersected nearly 300 m and was still in the Observatory Hill Beds when drilling was stopped.[5] Marla–1 well intersected 22.58 m of Observatory Hill Beds unconformably beneath the ?Early Permian Boorthanna Formation. The specimens described herein are from 87.85 m depth. Other, at present indeterminate, trilobite fragments have been found at a depth of 333 m in Marla–1B.

The Observatory Hill Beds in Marla–1B are a flat lying sequence of predominantly fine-grained, buff to grey, silty carbonates with minor thinly interbedded calcareous siltstones and sandstones. Above 176 m, calcite and dolomite mudstones and boundstones are common, with chert and fluorite occurring throughout. Below 176 m to the total depth of 379 m, the section is predominantly dolomitic and evaporitic mudstones with some boundstones, wackestones and packstones. Fine- to medium-grained calcareous and dolomitic siltstones and sandstones are interbedded throughout. Fluorite is rare, but secondary chert and sulphides are common.

Apart from algal mats and stromatolites throughout the sequence, the only fossils are trilobite fragments. These are found only at the top of the drilled section and were recorded at levels similar to those in Marla–1.

Unlike the Observatory Hill Beds in Byilkaoora–1 (Fig. 1) which are considered non-marine (White & Youngs 1980), those in Marla–1, –1B are interpreted as marginal marine. The basal 200 m were deposited on mudflats and in tidal channels which may have been subjected to periodic exposure. The beds above 176 m show an increase in marine influence and were probably deposited in the shallow, quiet waters of a lagoon on a broad, shallow platform.

Palaeontology

Several trilobite fragments were recovered from limestone core at a depth of 87.85 m in Marla–1, after having been discovered during petrographic work.[6] However, there are only three small, fragmentary specimens on which reasonable comment can be made. The smallest available specimen, P22981, is very small (Fig. 4a) and may be an immature form of the species described below. However, the glabellar furrows of P22981 seem to be shorter and less distinct and the anterior border is narrower than in that species. Until more and better material is available, it will not be possible to identify this specimen.

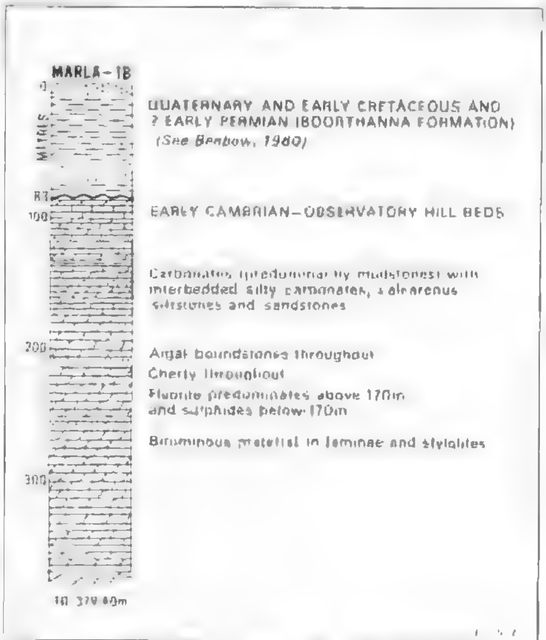

Fig. 3. Simplified log, Marla 1-B, Officer Basin, S.A.

[5] Benbow, M. C. (1980). Marla-1A, 1B well completion report. S.A. Dept Mines & Energy Rept Book 80/22 (unpublished).

[6] Lydyard, A. J. (1979). A petrographic study of the sediments in seven Officer Basin stratigraphic wells. S.A. Dept Mines & Energy Rept Book 79/55 (unpublished).

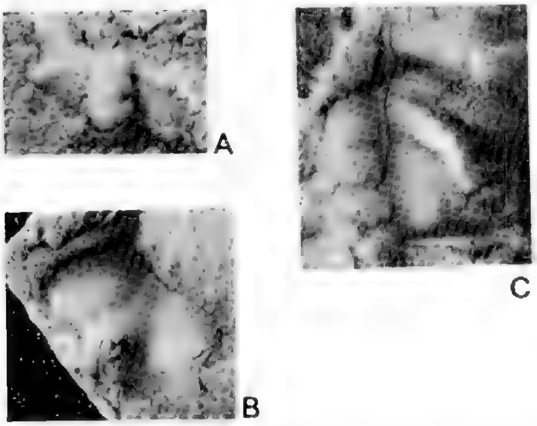

Fig. 4. A. P22981, immature cranidium, X9. B. P22982, part of left hand anterior part of cranidium, X8. C. P22983, partial cranidium, X7.5. All photographs are of silicone rubber casts whitened with magnesium oxide.

The other two specimens, P22982–3 (Figs 4B–C), represent a single species. This species has a glabella which apparently has a well developed occipital furrow and three pairs of lateral glabellar furrows. The lateral glabellar furrows are directed inwards and backwards, with the anterior furrows being shallower than the posterior furrows. The position of the glabellar anterior cannot be determined. The wide palpebral lobes extend from opposite the occipital furrow to opposite the 3p glabellar furrows; the wide eye ridges meet the glabella immediately forward of the 3p glabellar furrows. There is a suggestion of the presence of a para-frontal band.

The wide, almost flat border widens abaxially; it stands well above the preglabellar field from which it is separated by a narrow, shallow marginal furrow. The preocular sections of the facial suture commence opposite the 3p furrows and diverge markedly to the marginal furrow, from where they converge gently. The almost flat palpebral areas of the fixigenae are separated from the palpebral lobes by narrow shallow furrows.

The short, postocular sections of the facial sutures diverge markedly and enclose small posterolateral limbs. The marginal furrows are broad. The forward part of the glabella has a low reticulate ornament. The remainder of the cranidium visible is finely granulose.

The shape of the facial suture, and the shape and position of the palpebral lobes suggest affinity with *Pararedlichia, Eoredlichia, Wutingaspis, Chaoaspis* or a related genus of the Redlichiidae. Such genera are found in lower Lower Cambrian rocks of China (Chang 1966, Lu *et al.* 1974, Li 1980), France (Courtessole & Jago 1980), Vietnam and Morocco (Hupé 1953). In South Australia *Eoredlichia* has been recorded from Faunal Assemblage II in the Flinders Ranges (Daily 1972). Daily correlated this assemblage with the early part of the Atdabanian of Siberia. This suggests that the specimens figured herein are also of early Early Cambrian age. However, until more material is available a more precise age cannot be given. The presence of further trilobite fragments at a depth of 333 m in Marla 1B indicate that the fauna figured herein cannot be of earliest Early Cambrian age.

Acknowledgments

B. C. Youngs publishes with the permission of the Director-General, S.A. Department of Mines and Energy. Dr B. Daily (University of Adelaide) is thanked for useful advice and criticism.

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MUCKERA AND MILLBILLILLIE – AUSTRALIAN ACHONDRITIC METEORITES

BY M. J. FITZGERALD

Summary

The chemistry, mineralogy and petrographic features of two Australian achondritic meteorites are described in detail. The previously undescribed South Australian meteorite, Muckera, found on the Nullabor Plain in 1951, is classified as a howardite. One of the masses of the Millbillillie meteorite from central Western Australia is shown to be chemically and mineralogically similar to another mass presumably from the same fall. This new mass is classified as an eucrite.

MUCKERA AND MILLBILLILLIE—AUSTRALIAN ACHONDRITIC METEORITES

by M. J. FITZGERALD*

Summary

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The chemistry, mineralogy and petrographic features of two Australian achondritic meteorites are described in detail. The previously undescribed South Australian meteorite, Muckera, found on the Nullarbor Plain in 1951, is classified as a howardite. One of the masses of the Millbillillie meteorite from central Western Australia is shown to be chemically and mineralogically similar to another mass presumably from the same fall. This new mass is classified as an eucrite.

Introduction

Meteorites can readily be subdivided into two groups on the basis of bulk chemistry, with the individuals of one group having compositions resembling the sun. These undifferentiated meteorites are known as chondrites as most contain chondrules—small spheroidal bodies commonly having diameters of the order of one millimetre which typically contain varying amounts of crystalline material in dendritic or skeletal form, and glass, which may or may not be devitrified. Of the three major chondrite groups — carbonaceous, enstatite and ordinary—the carbonaceous chondrites best approximate pristine solar material even though they have undergone some alteration, albeit isochemical (McSween 1979).

Conversely, an achondrite is a meteorite whose chemistry is unlike that of the sun. Traditionally this term has been restricted to differentiated meteorites containing little or no free metal, but this restriction appears to conceal important genetic relationships.

The differentiated and undifferentiated meteorites can be distinguished on the basis of their chemistries relative to the C1 (type 1 carbonaceous) chondrites by evaluating the following ratios (atomic abundances normalized to 100 silicon atoms):

K/0.42, Al/8.5, Ca/7.21, P/0.96, Ti/0.2775 and Fe/83.0

with the divisors being the corresponding normalized abundances for the C1 chondrites from Cameron (1973). An undifferentiated meteorite is then defined as one for which these ratios generally fall in the range 0.4 to 1.3 while the achondrites fall outside.

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The achondrites can be subdivided into nine groups on the basis of selected atomic ratios (on a percentage basis) with almost every member of two of the groups, the eucrites and howardites, being characterized as follows:

	Eucrites	Howardites
Al/Si	$\overline{>10}$	
Fe/Si	<100	
Ca/Si	>20	<20

These two groups encompass a large proportion of the silicate-rich achondrites and because of their chemistry and mineralogy are often collectively referred to as the basaltic achondrites. They consist essentially of plagioclase and pyroxene with pigeonite generally predominating in the eucrites and hypersthene in the howardites. This predominance of calcium-rich pyroxene in the eucrites is reflected in the Ca/Si ratio used to characterize them.

Most of the eucrites and howardites are brecciated with the former being described as monomict breccias (i.e. they contain clasts which are similar in composition), although some of these meteorites show little evidence of brecciation. On the other hand the howardites, almost without exception, contain clasts which vary widely in texture and composition but which nonetheless appear to be closely related to each other and are thus described as polymict breccias (cf. Duke & Silver 1967, Wasson 1974, Mason *et al.* 1979). The basaltic achondrites resemble brecciated materials recovered from the lunar surface and it is likely that all are surface breccias produced by similar processes.

These chemical and petrological definitions are generally complementary and in most cases produce a consistent classification. However, there seems to be a genetic relationship

between the two groups which renders the distinction between them somewhat unnecessary. Furthermore, this relationship extends to other achondrite groups as presently defined and it is suggested that they should all be grouped together under the generic heading of "cognate achondrites".

Muckera Meteorite

Historical Background

On either May 1 or 2, 1951, while walking some 3 km SW of a group of rock holes on the northern edge of the Nullabor Plain about 70 km north of Cook and known as Muckera Rock Hole (30°05'S 130°02'E), Police Constable C. P. Doyle kicked a rock and, as it seemed different from the country rock, picked it up. Mr Doyle removed much of the covering crust in an attempt to identify the abnormally heavy rock but was not successful and so took it back to Cook. Ultimately the meteorite was brought to the Geology Department of the University of Adelaide in February 1972 where it was identified as a meteorite by Dr J. B. Jones. The meteorite was named Muckera. This name is sufficiently different from Mukerop, a rarely used synonym for the Gibeon meteorite, to avoid confusion.

This is the first published account of the Muckera meteorite other than the author's classification given by Hutchinson *et al.* (1977) and mentioned by Mason *et al.* (1979).

Description

The meteorite is approximately ellipsoidal in shape (Fig. 1), and about 10 × 8 × 5 cm. Part of the fusion crust which is commonly red-brown in colour due to terrestrial weathering is still preserved. This crust also contains occasional white mineral grains.

Internally the meteorite consists of sub-rounded to angular fragments, varying 0.1–3 cm, set in a dark grey to black groundmass. Small grains of nickel-iron and troilite, surrounded in most cases by weathering haloes, are present. Commonly the nickel-iron is confined to the clasts, while the dark colour of the matrix is due to the presence of fine-grained tarnished sulfides and glass. Olivine and calcium-rich pyroxenes are generally confined to the dark matrix whereas most of the calcium-poor pyroxenes are in the clasts. Numerous fractures and vughs, many of which are lined with, and commonly filled by, a brown mineral, are present. In some cases this filling is layered parallel to the cavity walls.

Many of the silicate clasts are white to cream, others are colourless. Many are aggregates of smaller, sub-rounded clasts which in turn are composed of angular and sub-rounded mineral fragments (Fig. 2).

Petrographic examination emphasises the brecciated nature of the meteorite (Fig. 3). The groundmass, containing abundant glass, is dark grey to black while the fragments are commonly light grey. Several different types of clast are present, ranging from mineral fragments through monomineralic aggregates to polymineralic lithic clasts.

The monomineralic fragments include both angular pyroxene and large plagioclase grains, many of which are strongly shocked and broken but not disaggregated. The monomineralic aggregates include fragments which in terrestrial rocks would be referred to as orthopyroxenites and anorthosites.

The lithic fragments include rock types such as basalts as well as numerous fine, equigranular breccia clasts containing angular to sub-rounded grains. Pyroxene is more abundant than feldspar in these pre-existing breccias and a glassy mesostasis is commonly present. There is generally little matrix material separating the small clasts which have been incorporated into the larger ones.

Muckera is thus a polymict breccia with a clast to matrix ratio of about 5:1, the latter being composed mainly of glass and small grains exhibiting a wide variation in grain size and composition. Such textures can be readily imagined as having been produced by repeated impacts on the surface layers of the meteorite parent body so producing fragmental material which was subsequently compacted and lithified.

Millbillillie Meteorite

Historical Background

At about 1 p.m. one day in October 1960, Messrs F. Quadrio and F. Vicenti, two station hands working near the boundary fence

Fig. 1. External view of Muckera meteorite. Absence of fusion crust reveals fragmental nature of meteorite. Scale 2 cm.
Fig. 2. Polished slab of Muckera meteorite showing brecciated texture. Scale 1 cm.
Fig. 3. Thin section of Muckera meteorite showing diverse nature of clasts. Scale 2 mm.

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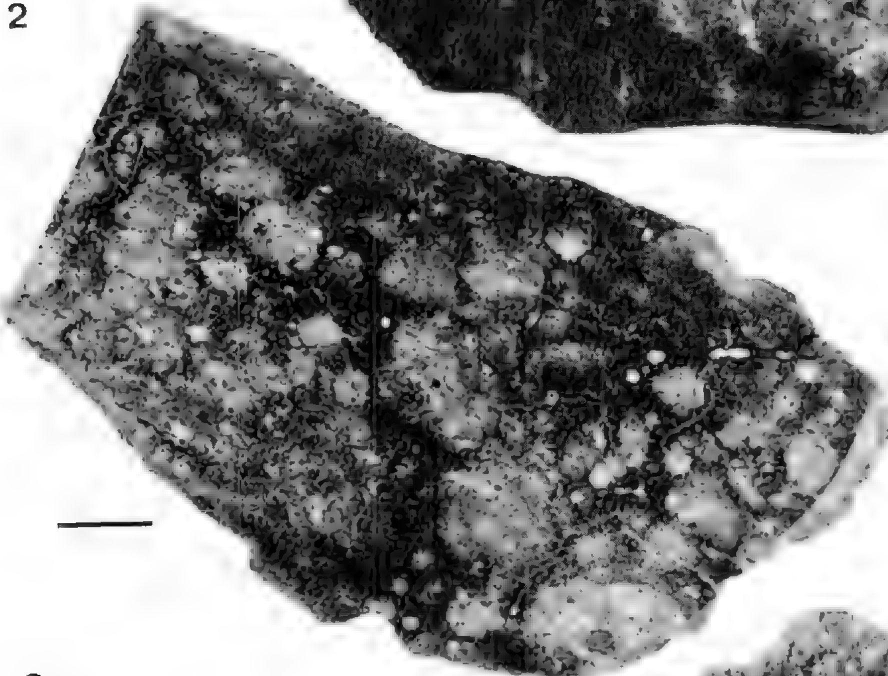

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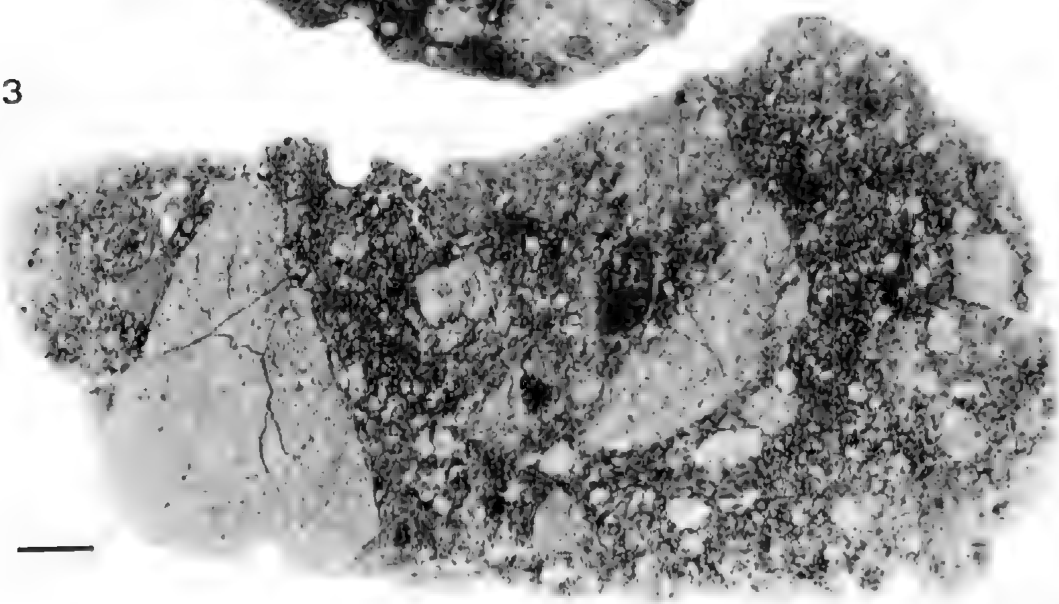

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Fig. 4. External surface of Millbillillie No. 3 meteorite showing fusion crust and radiating bubble trains. Scale 2 cm.

between Millbillillie and Jundee Stations in the Wiluna district, central W.A. (26°27′S 120°22′E), saw a fiery object trailing sparks fall on a spinifex-covered area of the plain to the north. No search was made but Mr D. Vicenti found a piece of meteorite on the plain in 1970. This mass weighed about 20 kg; another mass of some 600g was found the next year by Mr M. Finch (Clarke 1972).

Further material has been recovered in the area by local aborigines. The third recorded recovery was purchased by the late Mr Clem Latz of Adelaide thereby precluding its export from this country. This 368g individual was completely covered with a fusion crust when purchased, and from it a mass of some 26g was acquired by the University of Adelaide. A portion of this mass was used for the analyses described in this paper. Subsequently, the main mass of 233g was also acquired by the University. The designation No. 3 was appended to this mass to indicate that it is the third documented recovery from the area (cf. Graham 1980).

Oher specimens of the meteorite include those lodged in Museums in Perth, Sydney, Canberra and London and in private collections in Wiluna. All told it appears that at least 26 kg of material has been recovered.

Some results have been reported for the first mass found. Passing references to its petrography were made by McCall (1973) and several trace elements have been determined (De Laeter & Hosie 1978; McCulloch *et al.* 1976, 1977; Rosman & De Laeter 1978; and Smith *et al.* 1977). At least two bulk analyses have been carried out—one by Dr J. A. Nelen (Mason *et al.* 1979), and another by Dr R. A. Binns (Stolper 1977) which is yet to be published in full. This paper presents the first published results for the third mass.

Description

The No. 3 mass resembles a flattened ellipsoid with dimensions about $4 \times 7 \times 10$ cm (Fig. 4). It is completely encrusted with a black glassy layer about 0.3 mm thick underlain in turn by dark crystalline material and a further layer of a light coloured crystalline material. Much of the crust, which is patterned with numerous lines radiating from a central point on one of the flat surfaces, is now covered with an orange film. The surface lines consist of trains of numerous dark brown to black glassy bubbles about 0.5 mm in diameter; other bubbles are randomly distributed over the remainder of the crust. Furthermore, the crust exhibits a series of polygonal fractures commonly forming quadrilaterals with dimensions about 2–5 mm. The individual cracks are less than 0.1 mm wide and are filled with the orange material which covers part of the crust surface. In places this filling stands above the level of the surface and in other cases below. In general, the fractures do not extend through the fusion crust. However, in rare examples where the fractures do pass through the crust, the secondary orange mineral occurs along the interface between the crust and the interior mass of the meteorite. In some places the orange mineral is, in its turn, overgrown with an apple-green one.

A cut surface shows numerous sub-angular particles from 0.1–3 cm set in a grey to white crystalline matrix. A sub-ophitic texture can be seen in some of the coarser-grained clasts even at low magnification. Clast-rich and clast-poor regions define a layering. Finer-grained clasts generally possess very sharp boundaries whereas the coarser ones commonly merge into the matrix, the grain size of which increases in that area, resulting in the average grain size

of the clast-rich regions being greater than that of the clast-poor regions. No metal or sulfide grains were seen on the surfaces examined.

The two clast types are readily seen in thin section (Fig. 5). The finer consist of extremely fine-grained granoblastic aggregates containing many opaque grains while the coarser clasts are ophitic and subophitic basalts, that is, feldspar and pyroxene aggregates. The feldspar laths in these basaltic areas vary in length up to 0.5 mm while occasional equidimensional grains achieve similar dimensions. In addition to these clasts there are also numerous feldspar fragments and spherulitic aggregates of devitrified glass. The silicate grains contain numerous opaque inclusions. The merging of the coarse-grained clasts and matrix is even more obvious in thin section and some of the matrix is also basaltic in texture. The layering seen on the macro scale can also be seen in thin section. There is no evidence of brecciation either within the basaltic clasts or in the host matrix.

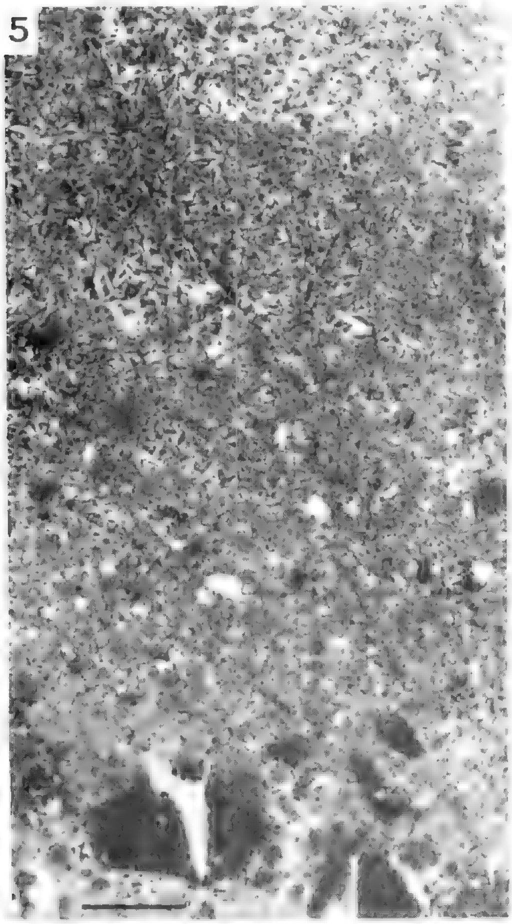

Fig. 5. Thin section of Millbillillie No. 3 meteorite showing grain size variation. Scale 2 mm

The matrix consists of tiny (0.02–0.03 mm) grains of pyroxene and feldspar set in glass with an overall texture of "feathery" quench material. Much of the matrix has been devitrified and recrystallized. There is no evidence of weathering in the form of iron-staining but the matrix appears dark due to the presence of numerous grains of opaque minerals and regions of opaque glass.

It is concluded that the fine-grained clasts may have been incorporated into the matrix prior to crystallization. There are several ways of achieving this—one possibility is that pre-existing clasts (possibly impact-derived fragments of a rapidly cooled lava flow) were caught up in a later flow which initially cooled less rapidly perhaps as a more extensive lava flow or blanket. During this cooling stage, gravitational setting could have brought about the layering. Subsequent rapid crystallization arising from changes in the cooling regime or the attainment of conditions of supersaturation in the liquid phase could have produced the glass in the matrix. Regardless of the exact mode of formation of the texture, subsequent shock events must have been minimal as any such significant reworking would have destroyed this layering.

Bulk chemical compositions

X-ray fluorescence analysis was used for the determination of all elements except sodium for which a flame photometric method was employed. A modified version of the Norrish & Hutton (1969) technique for XRF analysis was used. Mineral compositions were determined with a Technisch Physiche Dienst microprobe fitted with a lithium drifted silicon detector, the method of Reed & Ware (1975) being used to reduce the data. Full details of all methods are given in Fitzgerald (1979).

The bulk chemical compositions of the meteorites are listed in Table 1 along with the results of normative mineral calculations. The assumptions made in the modified form of the CIPW calculations used to calculate the norm are fully explained in Fitzgerald (1979). Phosphorus has been allocated to the mineral merrillite, (β–$Ca_3(PO)_2$), as Dowty (1977) has shown this is the principal meteoritic phosphate. For comparative purposes, Table 2 also lists the results of Mason *et al.* (1979).

TABLE 1. *Bulk chemical composition and normative mineralogy.*

Elemental abundances (weight percent)	Muckera[1]	Millbillillie No. 3[1]	Millbillillie No. 1[2]
Fe	13.85	15.30	14.22
Mn	0.40	0.46	0.47
Ti	0.25	0.44	0.41
Ca	5.06	7.42	7.29
K	0.060	0.071	
P	0.029	0.034	
Si	23.20	23.89	24.31
Al	4.32	7.03	6.77
Mg	8.95	4.42	4.08
Ni	0.090	0.015	
S	0.27	0.003	
Cr	0.37	0.21	0.23
Na	0.21	0.33	0.29
Normative mineralogy (weight percent)			
Nickel-iron	0.7	0.1	
Troilite	0.7	0.01	
Merrillite	0.1	0.2	
Ilmenite	0.8	1.3	
Chromite	0.8	0.4	
Feldspar	23.9	34.3	
Diopside	11.5	13.0	
Orthopyroxene	61.0	41.9	
Olivine	0.5		
Quartz		8.9	
Molar percent composition			
Ab	11	11	
An	88	88	
Fs	35	60	
Fa	3		

[1]This work [2]Mason *et al.* (1979)

As Mason (1962) pointed out, there is an almost perfect balance between silica and the basic oxides in the basaltic achondrites so that a slight excess results in quartz being present or a slight deficit appears as olivine. The excess silica generally occurs in the eucrites and the olivine in the howardites. The normative calculations of Table 1 illustrate this.

Mineralogy

Eucrite and howardite feldspars commonly fall in the compositional range An_{80-95}, with most compositions lying in the narrower range An_{85-90} (Duke & Silver 1967). Feldspar compositions measured in this work (Table 2) lie within these limits and are accordingly consistent with the classifications proposed below

The pyroxene variation in Muckera (Fig. 6) is very similar to that of the Kapoeta and Malvern howardites (Desnoyers & Jerome 1977; Duke & Silver 1967; Dymek *et al.* 1976; Simpson 1975). The majority of the analyses fall within the field $En_{80}Fs_{20}$–$En_{30}Fs_{70}$–$En_{30}Fs_{50}Wo_{20}$–$En_{60}Fs_{20}Wo_{20}$. This variation is in distinct contrast to that of the eucrites.

In these cases Duke & Silver (1967) found a continuous range in composition from pigeonite through sub-calcic ferroaugite to ferroaugite with the magnesium silicate component remaining relatively constant. Figure 7 shows such a situation for Millbillillie and, except that the most calcium-rich analyses show about 5 mole percent more of the calcium silicate component than the results of Duke & Silver, the distribution most closely resembles that of Juvinas as figured by these authors. A more recent determination (Takeda *et al.* 1978) shows an even closer resemblance between Juvinas and Millbillillie. The Millbillillie results are also very similar to those obtained by Desnoyers & Jerome (1977) for a clast in the Malvern howardite. Simpson (1975) and also Wilkening & Anders (1975) have suggested that this apparent linear series of compositions, which is characteristic of eucritic pyroxenes, results from the analysis of differing proportions of two exsolved phases, the lamellae being too fine to resolve with the microprobe. Mason *et al.* (1979) came to a similar conclusion. Micron-sized lamellae visible in many of the Millbillillie pyroxene grains are probably thus responsible for the trend seen in Figure 7.

Modal olivine was not observed in Millbillillie and minor amounts only in Muckera. In the latter it was confined almost exclusively to the dark groundmass with only a few grains being found in lighter clasts. The com-

TABLE 2. *Mineralogical compositions.*

	Muckera[1]	Millbillillie No. 3[1]	Millbillillie No. 1[2]
Feldspar (% An)			
Range	74 to 94	78 to 92	82 to 91
Average	88	84	88
Pyroxene	—	$Fs_{62}Wo_{2}$ to $Fs_{26}Wo_{44}$	$Fs_{60}Wo_{2}$ to $Fs_{26}Wo_{45}$

[1]This work [2]Mason *et al.* (1979)

Fig. 6. Pyroxene compositions in Muckera meteorite.

Fig. 7. Pyroxene compositions in Millbillillie No. 3 meteorite.

positional range Fa_{24-35}, as measured by microprobe, is consistent with the results of Desnoyers & Jerome (1973). These modal results are in accord with the normative calculations of Table 1.

The iron-manganese correlation in lunar, meteoritic and terrestial olivines and pyroxenes is well documented with the three groups being fairly readily distinguished on this basis (Desnoyers & Jerome 1973; Dymek *et al.* 1976; Simkin & Smith 1970). The correlation arises as a result of the ability of Mn^{2+} to replace Fe^{2+} in olivine and pyroxene lattices due to the similarity of their ionic radii (Wanke *et al*, 1973). Intergrain constancy of this ratio indicates the grains have been derived from related source materials (Dymek *et al.* 1976).

The Muckera pyroxenes and olivines show a wide range in iron and manganese contents. That the pyroxene data is somewhat non-cohesive is shown by the correlation coefficient of 0.91 for 118 determinations. The average Fe/Mn ratio for the pyroxenes is 28.8, while the value for the bulk analysis is 33.9 (Fig. 8).

A relatively narrow range in iron composition in the olivine, coupled with a considerable spread in manganese values, results in the relationship between these elements in the olivine grains being less obvious (Fig. 8), with the spread being indicated by the lower correlation coefficient of 0.34 for the 50 analyses. The average value of the ratio for the olivine is 50.3, thereby explaining the difference between the bulk ratio and that of the pyroxenes.

In Millbillillie the pyroxenes also exhibit a wide range in Fe and Mn values but the data is even more cohesive as shown by the correlation coefficient of 0.97 for the 103 analyses (Fig. 9). The value of the ratio for the bulk analysis is 33.1 while the average value for the pyroxene analyses is 32.9. Similar agreement of pyroxene and bulk chemistry is shown by eucrites such as Moama (Lovering 1975) which has a bulk ratio of 29.3 and one of 27.5 for the host hypersthene.

Classification

Table 3, giving values for several atomic ratios discussed previously, clearly shows that both Muckera and Millbillillie are differentiated meteorites while Table 4 shows that, on the basis of the ratios listed here, Muckera is a howardite and Millbillillie an eucrite.

Feldspar, pyroxene and olivine contents and compositions are consistent with these classifications as are the petrological descriptions showing Muckera to be a polymict breccia and Millbillillie monomict. Muckera is thus

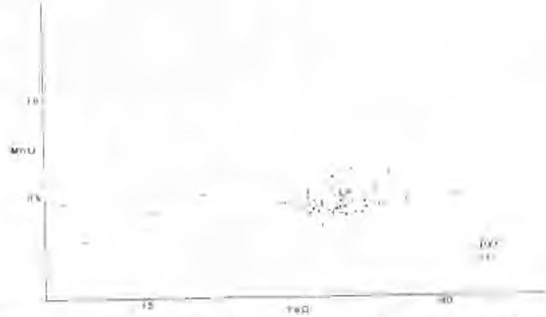

Fig. 8. Plot of MnO versus FeO in Muckera meteorite olivines and pyroxenes. X: bulk composition.

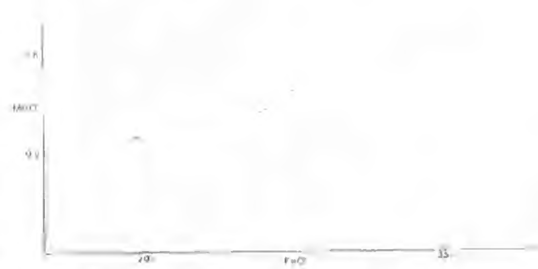

Fig. 9. Plot of MnO versus FeO in Millbillillie No. 3 meteorite pyroxenes. X: bulk composition.

TABLE 3. *Evaluation of "differentiation" ratios on atomic basis.*

	K/0.42	Al/8.5	Ca/7.21	P/0.96	Ti/0.2775	Fe/83.0
Muckera	0.5	2.3	2.1	0.1	2.3	0.4
Millbillillie No. 3	0.5	3.6	3.0	0.1	3.9	0.4

TABLE 4. *Classifications based on atomic ratios (on a percentage basis).*

	Ratios			Classification
	Al/Si	Fe/Si	Ca/Si	
Muckera	19.4	30.2	15.3	Howardite
Millbillillie No. 3	30.6	32.4	21.8	Eucrite

the first recorded example of a polymict brecciated achondritic meteorite to be recovered in Australia.

On the basis of chemical and textural features it has been suggested (e.g. Stolper 1977) that most of the known eucrites lie together in a cohesive group with the others in two smaller groups with one containing eucrites described as cumulates and the other meteorites considered to be residual fractions. Application of the technique of Principal Component Analysis by the author (Fitzgerald 1979) to a data set including analyses of 32 eucrites has shown that Millbillillie belongs to the main body of the eucrites, an assignment which is supported by the textural relationships described above.

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